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EVALUATION OF RAPESEED AND RAPESEED MEAL AS ENERGY AND PROTEIN SOURCES FOR CHICKENS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Evaluation of rapeseed and rapeseed meal as energy and protein sources for chickens" submitted by Julius MacDonald Olomu, B.Sc. (Nutritional Biochemistry), in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Poultry Nutrition.

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ABSTRACT

Experiments were conducted with broiler chicks to study the effect of processing and amino acid supplementation on the nutritive value of rapeseed. Studies were also conducted to assess the utilization of rapeseed and of rapeseed meal by laying chickens.

Results showed that chicks fed rations containing raw rapeseed gained weight more slowly and required more feed per unit of gain than chicks fed rations containing rapeseed heated in the autoclave for 10 minutes at 120C or those fed a control ration. Supplementation of rations containing autoclaved rapeseed with methionine and arginine, singly or in combination, consistently improved weight gain of chicks. No further improvement was obtained by the additions of lysine, threonine, histidine and tryptophan to autoclaved rapeseed rations already supplemented with arginine or methionine.

Rations containing raw rapeseed caused thyroid enlargement. Autoclaving the seed for 10 minutes at 120C reduced this effect and destroyed myrosinase activity in the seed. The use of either raw or heated rapeseed had no significant effects on the relative weights of the testes, spleens or pancreas. The inclusion of raw rapeseed had no effect on size of livers and hearts except in one trial in which significant enlargement of the livers occurred.

The inclusion of raw rapeseed in chick rations resulted in leaner carcasses than those noted on the control ration. Carcass compositions of chicks fed autoclaved rapeseed ration fell midway between those noted on the ration containing raw rapeseed and those obtained on the control ration. There was no evidence of fat

accumulation in the livers and hearts of chicks fed rations containing rapeseed.

The use of ground rapeseed in the ratio of chicks caused a reduction in the utilization of dietary energy as compared to a control ration. As a result the metabolizable energy value of the rations containing rapeseed was lower than that of the control. Protein utilization of the ration was not adversely affected by the inclusion of rapeseed in the ration.

The use of Span rapeseed meal in rations of laying chickens indicated that levels of 5 or 7.5% had no adverse effects on egg production or egg quality. The inclusion of 10% rapeseed meal in the ration, however, reduced egg production and increased level of mortality. The proportion of mortality attributed to "fatty liver syndrome" increased with increase in the level of rapeseed meal in the ration. Inclusion of rapeseed meal in the ration caused thyroid enlargement but did not significantly affect the relative weights or compositions of the livers and hearts of laying chickens.

The inclusion of 5, 10 or 15% Span rapeseed in the ration of laying chickens did not significantly affect egg production or egg quality, although egg production decreased slightly with increase in the level of rapeseed in the ration. Mortality attributed to "fatty liver syndrome" was significantly higher in the groups fed 10 or 15% rapeseed than in those fed the control ration or 5% rapeseed. The addition of rapeseed resulted in a progressive increase in thyroid weight as the level of rapeseed in the ration was increased. Size and composition of the hearts and livers of laying chickens were not significantly affected by the use of rapeseed in the rations fed.

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INTRODUCTION

Production of rapeseed throughout the world has increased greatly from a level of 2.8 million tons in the period, 1948-1952, to over 6 million tons in 1970. At the same time, production in Canada has risen from a mere 9000 tons in the 1948-1952 period to 1.6 million tons in 1970. Production in Canada in 1973 was approximately 1.3 million tons.

As a result of increased rapeseed production in Canada, large quantities of rapeseed may be available for use in animal feeds. While rapeseed meal may be the principal product used in commercial feeds, the potential for use of unextracted rapeseed in poultry rations is attractive because of its high energy and reasonably high protein content. Because of its high fat content, the seed might be used as a partial or complete replacement for ingredients such as stabilized tallow in poultry rations.

Since information on the use of full-fat rapeseed in poultry rations is limited, studies on the use of this material in rations for broilers and laying hens were undertaken. Trials with laying hens were also conducted to obtain additional information on the use of rapeseed meal in rations for laying chickens.

REVIEW OF LITERATURE

The oilseed denoted "rapeseed" (RS) belongs to the family of plants or their seeds collectively termed Cruciferae to which the genus, Brassica belongs. Present varieties of RS belong to two species of this genus--Brassica campestris, also known as Polish rape, and Brassica napus, known as Argentine rape, (Downey, 1965).

Rapeseed has a high oil content (about 40%) and the oil, after extraction from the seed, is used in the manufacture of margarine and shortenings and as a salad and cooking oil. The extraction of oil leaves a high protein residue known as rapeseed meal (RSM) which can be used in livestock and poultry feeding. The composition of RSM is essentially similar to other high quality protein supplements of plant origin such as soybean meal (SBM); however some problems have been encountered when RSM is used in poultry rations. Some of the problems relate to the presence of deleterious substances in the seed known as glucosinolates.

I. Glucosinolates in rapeseed

Glucosinolates are present in RS in only small amounts. They are distributed diffusely in the parenchymal tissues of the seed which also contains, in special cells, an endogenous enzyme system, myrosinase, with the ability to hydrolyze glucosinolates (Guignard, 1890, as reviewed by Josefsson, 1972) under optimum conditions to yield principally isothiocyanates, glucose, sulfate and in some cases, nitriles. From various references, Josefsson (1972) listed the following glucosinolates as occurring in RS: 3-butenyl glucosinolate (gluconapin), 4-pentenylglucosinolate, 4-methylthiobutylglucosinolate, 5-methylthiopentylglucosinolate, 4-methylsulphinylbutylglucosinolate, 5-methylsulphinylpentylglucosinolate, 2-phenylethylglucosinolate, 2-hydroxy-3-butenyl glucosinolate (progoitrin) and 2-hydroxy-4-pentenyl glucosinolate. Of those listed, only two or three are present in large amounts (Wetter, 1965; Van Etten et al., 1969; Josefsson, 1972). In Brassica napus, progoitrin is the predominant glucosinolate with gluconapin in second place while in Brassica campestris, gluconapin predominates while progoitrin is low in amount in this species (Clandinin et al., 1959; Wetter and Craig, 1959; Appelqvist, 1962; Daxenbichler et al., 1964). The variety with the lowest reported glucosinolate content belongs to the Brassica napus species and is called Bronowski (Josefsson and Appelqvist, 1968; Downey et al., 1969).

Of major concern to RS users is the presence in RS of progoitrin, which on hydrolysis by the enzyme, myrosinase, yields glucose, bisulfate, 2-hydroxy-3-butenyl isothiocyanate and sometimes nitriles. The 2-hydroxy-3-butenyl isothiocyanate is unstable and cyclizes to the goitrogenic substance, -5-vinyl-2-oxazolidinethione (goitrin). The scheme of the reactions according to Van Etten et al. (1969) is shown in Figure 1 on page 4.

The products formed from progoitrin depend on conditions of hydrolysis and other unidentified variables (Virtanen, 1965; Van Etten et al., 1966). According to Daxenbichler et al. (1965, 1967), the product of hydrolysis of progoitrins in RSM include either goitrin, nitriles or a mixture of these compounds. The environmental conditions under which the RS grows and variety of RS are factors

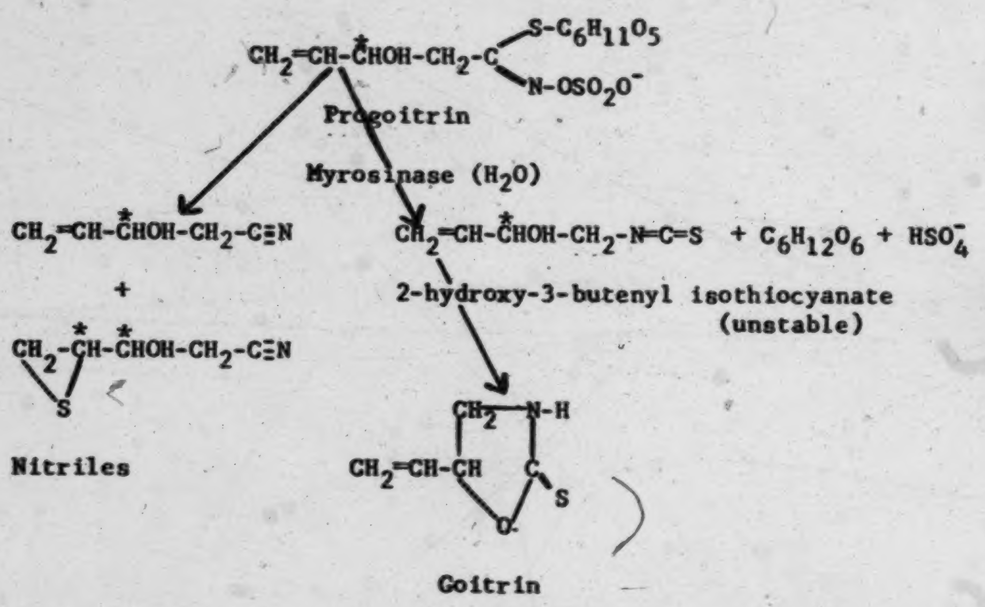

Figure 1. Products from progoitrins formed during meal autolysis.

likely to affect the amount of goitrin in RS (Clandinin et al., 1959; Wetter et al., 1970).

The products formed by the enzymatic reaction (isothiocyanates, goitrin and nitriles) may exert harmful effects on animals but the effect of goitrin has been studied most because it has been more consistently implicated in the goitrogenicity of RSM. Interest in the study of goitrin arose from the early report of workers (Kennedy and Purves, 1941; Pettit et al., 1944; Turner, 1946, 1948) who showed that the inclusion of RS or RSM in the rations of rats or chicks depressed performance and caused enlargement in the thyroids of these animals. Goitrin, isolated and characterized from RS (Astwood et al., 1949 and Carroll, 1949) has been shown to be the principal compound in RS responsible for the enlargement of the thyroid and depression of the thyroidal functions in animals fed RS (Greer, 1962). Such a conclusion has also arisen from studies with chicks in which the inclusion of isolated goitrin in the ration resulted in thyroid enlargement (Clandinin et al., 1966b; Matsumoto et al., 1968; Lodhi et al., 1970a).

Goitrin acts principally by inhibiting the organic binding of iodine in the thyroid. By such inhibition, it interferes with the synthesis of thyroxin, whereupon the anterior pituitary is stimulated to produce thyroid stimulating hormone which acts on the thyroid glands causing hypertrophy and hyperplasia (Josefsson, 1972). Matsumoto et al. (1969) showed with chicks that goitrin also interfered with the secretion of the thyroid hormone into the blood. Although the thyroid enlargement occurs when goitrin or RS is fed, the animals appear to reach physiological equilibrium with respect to thyroid hormone secretion rate at increased thyroid to body weight ratios (Kennedy and Purves, 1941; Clandinin et al., 1966b) after 3-4 weeks on treatment. In addition to goitrogenesis, growth depression as a consequence of feeding goitrin to chicks was also reported (Clandinin et al., 1966b).

II. Effects of processing on the nutritive value of rapeseed and rapeseed meal

Processing methods for improving the nutritive value of RSM and full-fat RS have been described (Frolich, 1953; Woodly et al., 1972). The processing methods used may be classified as solvent extraction, aqueous extraction, and application of heat.

1. Solvent extraction

a. Acetone extraction

Daxenbichler et al. (1965) and Van Etten et al. (1965) used 80%

acetone to extract all of the glucosinolates from Crambe abyssinica, a member of the Cruciferae family to which RS also belongs. Van Ætten et al. (1965) observed that acetone extraction of Crambe meal resulted in its nutritive value being improved to the point of making it equal to a control ration for rats; unprocessed Crambe meal resulted in mortality rate close to 100%.

b. Alcohol extraction

Some studies have shown that extraction of RSM with 70-95% ethanol improved its nutritive value for chicks (Frolich, 1953). More recently, Josefsson and Munck (1972) noted that extraction or soaking of RSM with 80% ethanol improved its nutritive value for mice. Ethanolic sodium hydroxide has been used in experimental work to detoxify RS via diffusion extraction of glucosinolates (Kozlowska et al., 1972; Bhatty and Sosulski, 1972).

Although acetone and ethanol methods for detoxifying RSM look promising, they have disadvantages. For example, acetone: water extraction may result in some loss of solids present in the meal (Van Ætten et al., 1965) and ethanol extraction may have a similar effect (Kozlowska et al., 1972).

2. Aqueous extraction

a. Co[illegible] water extraction

Improvement in the nutritive value of RSM via cold water extraction has been demonstrated for cockerels by Frolich (1953). Similar beneficial effects of cold water extraction of RSM have been reported for other species of animals (Bell and Williams, 1953; Ballester et al., 1973). The improvement in the nutritive value of

RSM by cold water extraction may be due to removal of goitrin and isothiocyanates. For example, Ballester et al.(1973) observed that 30 minutes cold water extraction reduced the quantities of both goitrin and isothiocyanates in RSM by 87%. Kozlowska et al. (1972) however, outlined some disadvantages of this method. These include loss of about one-third of the meal proteins, dark colour of the extracted meal, and difficulty in drying the wet slurry of the extracted meal.

b. Hot water extraction

Hot water extraction of RSM has been shown to improve its nutritive value for chickens (Allen and Dow, 1952; Nakaya, 1964) and for mice (Belzile et al., 1963). The results of Lo and Hill (1971) indicated that the mere dipping of Bronowski RS in hot water considerably improved its nutritive value for rats.

Belzile et al. (1963) and Lo and Hill (1971) noted that the treatment of RSM or RS with hot water inactivated the enzyme, myrosinase. In addition, some of the glucosinolates were extracted by hot water (Belzile et al., 1963; Lo and Hill, 1972). Hot water extraction, however, resulted in removal of 20% or more of dry matter (Belzile et al., 1963; Lo and Hill, 1972) and some loss in protein (Lo and Hill, 1972).

3. Application of heat

a. Dry heat

Dry-heating has not consistently improved the nutritive value of RSM for monogastric animals. Frolich (1953), working with chicks, observed that while heating up to 100C for 24 hours did not reduce the goitrogenic activity of RSM, it had a growth promoting effect. When the temperature was raised to 130 C for 24 hours or 150 C for 5 hours, the goitrogenic activity was reduced, though the higher temperatures reduced the growth stimulation found with the lower temperatures. Van Etten _et_ _al_. (1966) reported that myrosinase activity remained after dry heating in open trays at 128-134 C for 3 3/4 hours although there were some losses in glucosinolates. It was only when heating was more extensive (140 to 160 C for 12 hours) that myrosinase activity was destroyed. The latter observation provided support for the later observations of Rutkowski (1970) that only dry calcination at 130 C or 150 C will bring about an effective decrease in goitrogenic properties of RSM. The results of Bell _et_ _al_. (1972) with mice seemed to indicate that dry-heating was ineffective in improving the nutritive value of unextracted RS for mice while that of Josefsson and Munck (1972) showed that dry-heating was effective in improving the nutritive value of RS. The conflicting results may be explained on the basis of the differences in moisture contents of the seed before heating, since Josefsson and Munck (1972) adjusted the moisture content of the RS used before heating.

Woodly _et_ _al_. (1972) subjected RS to heating temperatures ranging from 232 to 427 C for periods of from 1 minute to 5 seconds and reported some improvement in the nutritive value of RS so processed. Although their results showed some improvement in the nutritive value of RS when so heated, the response of chicks was variable and thus no definite temperature-time relationship could be established nor could the thyroid weights of chicks be reduced by such heat treatment.

b. _Moist heat_

The beneficial effect of heating in an autoclave on the nutritive value of RSM for chicks has been demonstrated. Gray _et_ _al_.

(1958) obtained data which showed that heating for 10 minutes at 15 lb pressure decidedly improved the nutritive value of Argentine RS for chicks. Recently, Bell et al. (1972), on the basis of experiments with mice, also demonstrated the beneficial effect of autoclaving RS.

The beneficial effect of autoclaving RS may be due to the destruction of myrosinase and reduction of glucosinolates (Van Etten et al., 1966; Bell and Belzile, 1965). That autoclaving destroys myrosinase activity in RS is perhaps responsible for its routine use in experimental work to free RSM of myrosinase (Belzile et al., 1963; Agren and Eklund, 1972). Use of high temperature for extended periods has been shown to cause deterioration in protein quality of RSM (Bell and Belzile, 1965).

III. Effects of amino acid supplementation on the nutritive value of rapeseed and rapeseed meal

The processing techniques described in the previous section were mostly designed to remove any depression in nutritive value of RS or RSM caused by the presence of glucosinolates or myrosinase. Such processed seed or meals may still be improved by amino acid supplementation. The need for supplementing rations containing RS or RSM with amino acids arises from a number of factors. Lodhi et al. (1970b) reported nitrogen absorbability to be significantly lower when RSM was the sole source of protein as compared to when SBM was the sole source for both chicks and hens. Lower availabilities of lysine (Guo et al., 1971) and of methionine (Oh et al., 1972) have been reported for chicks fed RSM as compared to SBM. Bin-heating of RS during storage has been found to result in marked reductions in the essential amino acids: arginine, histidine, threonine, tryptophan and lysine (Bell et al., 1972). Clandinin and Bayly (1963) noted that the environment under which RS was grown had a highly significant effect on the lysine content of RS and significant effects on the histidine, arginine, phenylalanine and leucine contents. Varietal differences in the lysine content of RS were also reported by Clandinin and Bayly (1963).

The conditions used during processing of RS has also been shown to affect the amino acid status of the meal. Gray et al. (1957) and Clandinin and Tajcnar (1961) observed that heating employed during commercial processing of RS could result in losses of amino acids, notably lysine. The destruction of lysine during processing probably explains why chicks fed rations containing commercial RSM responded to lysine supplementation (Kratzer et al., 1954; Klain et al., 1956; Gray et al., 1957; March and Biely, 1971). Gray et al. (1958) indicated that excessive autoclaving caused losses of lysine, tryptophane and tyrosine.

That other amino acids, as well as lysine, may be destroyed by heat-induced reactions has been demonstrated with other protein products (Anantharaman and Carpenter, 1971; Bjarnason and Carpenter, 1970). Anantharaman and Carpenter (1971) cited the work of other researchers who showed that, with the very severe conditions required to produce damage to lysine in the presence or absence of sugars, the availability of all amino acids seem to be reduced to the same extent as lysine. These observations, coupled with possible deficiencies of arginine, phenylalanine, tyrosine and lysine (Klain et al., 1956); arginine and aspartic acid (Sosulski and Sarwar, 1973) in RSM probably indicate that rations containing RSM might respond favourably to additions of certain amino acids. Such favourable responses have been reported for chicks by March and Biely (1971) and for laying birds by Summers *et al*. (1971).

IV. Effects of rapeseed oil on the nutritive value of rapeseed

Since RS contains about 40% oil, its value in relation to other oils or fats is important in assessing the nutritive value of full-fat RS for poultry. There is, however, little information on the nutritive value of rapeseed oil (RSO) for chicks. Sell and Hodgson (1962) observed that the performance of chicks fed 4 or 8% RSO in the ration was similar to that of those receiving the same levels of soybean oil or tallow. None of the fat sources caused any appreciable change in the thyroid weights of chicks. Tsang *et al*. (1962) made similar findings when they reported that RS screening oil was as good as the same levels of stabilized yellow grease for chicks. Salmon (1969) noted that the substitution of RSO for soybean oil in rations containing 10% total added oil depressed the growth of chicks up to 41 days of age, although the metabolizable energy of the rations was approximately the same. Slinger (1969) reported depression of growth and feed consumption of chicks fed rations containing undegummed RSO while degummed RSO did not cause any such depression in growth and feed consumption. These observations were confirmed by Walker *et al*. (1970) and Lall and Slinger (1973). The latter workers observed that the inclusion of 20% undegummed RSO in rations of chicks resulted in lower weight gain and feed consumption as compared to those obtained on rations containing the same levels of degummed RSO or stabilized tallow. When low-erucic acid RSO was included in the ration in place of other oils, weight gain and feed conversion efficiency were superior to those of chicks fed rations containing any other single source of fat or oil. Consistent with the earlier findings of Slinger (1969), Walker et al. (1970) and Lall and Slinger (1973) noted a beneficial synergism when RSO was mixed with animal tallow or with some saturated fatty acids. The results indicated that the low levels of saturated fatty acids in RSO was a limiting factor in its optimum utilization. Walker et al. (1970) also suggested that the erucic acid content of the oil might be responsible for reduced performance of chicks fed high erucic acid RSO, an implication consistent with that of others working with rats (Abdellatif and Vles, 1970c). Vogtmann et al.,(1973) obtained results which showed that, in spite of the high digestibility obtained for various types of RSO (regular, Span and Canbra) in comparison to soybean oil and lard, weight gain was lowest on the ration containing regular RSO, next on Span RSO and highest on rations containing Canbra oil, soybean oil and lard.

V. Effects of feeding rapeseed, rapeseed oil or rapeseed meal on carcass, liver and heart characteristics of monogastric animals

No information is available on the effect of feeding full-fat RS on the composition of the carcass, liver and heart of chicks; however some data have been reported on the effect of RSM on the body composition of chickens and rats. Meier et al. (1967) fed White Leghorn chicks SBM and RSM, amongst other protein sources, and reported maximum nitrogen utilization determined via HCl-hydrolysed carcasses as 36.8% for SBM and 29.8% for RSM. Nakaya et al. (1968) analysed the breast and leg meat of chicks fed various levels of RSM in place of

SBM in their rations and reported no differences in the moisture, crude protein and crude fat percentage contents of these parts of chicks up to 10 weeks of age. Work with rats indicated leaner carcasses when RSM was included in their diets (Drouliscos and Bowland, 1969). This occurred in spite of the fact that in most cases the nitrogen digestibility and utlization of rats on RSM treatments were at least twelve percentage units less than those on control diets containing SBM or casein. Recently Ballester et al. (1973) observed that the inclusion of RSM in diets resulted in leaner carcasses in rats than the inclusion of RSM that had been extracted with cold water.

Bowland (1971) recorded the effect of feeding full-fat RS on the carcass composition of pigs. Leaner carcasses were obtained when full-fat RS was included in rations for pigs as compared to pigs fed a ration containing SBM.

Although little data are available in the literature concerning the effect of inclusion of RSO in rations on the gross carcass composition of chicks, some information is available on the effect of feeding RSO on the organ characteristics of most monogastric animals. Sheppard et al. (1971), working with both White Plymouth Rock and White Leghorn chicks observed that a level of 16% RSO in the ration resulted in increased liver weights in comparison to chicks fed a ration containing 16% corn oil. The differences in liver weights could not be explained by differences in fat contents of the fresh livers. Heart weights were not significantly affected by dietary treatments used. Salmon (1970), working with turkeys reported increased enlargement of the heart with increasing levels of RSO in the diet; the enlargement attained significance when 7.5 or 10% RSO replaced an equal amount of animal tallow. The spleens were reduced in size in turkeys fed the highest level of RSO. Neither erucic acid nor degree of unsaturation of fatty acids of the oils appeared to be responsible for the effects noted. No evidence of fatty infiltration in any of the organs studied were reported by Sheppard *et al*. (1971) or Salmon (1970).

That fatty infiltration of certain organs (particularly heart and liver) may occur in poultry has been demonstrated. Abdellatif *et al*. (1970b, 1971 and 1972) reported that the feeding of high levels of RSO containing high levels of erucic acid to ducklings resulted in fatty infiltration of the heart and liver and consequently higher free fatty acid content of these organs. The absolute mean liver weights of ducklings increased with increase in levels of RSO (hypertrophic cirrhosis) but decreased as the level of RSO was further increased (atrophic cirrhosis). The relative liver weights of the birds did not show any set pattern due to RSO levels in the diets but the absolute and relative heart weights increased with increasing levels of RSO in the diet. It was suggested that the high erucic acid content and the low level of palmitic acid in the RSO were possible causative factors in the onset of the morphological and pathological effects observed.

Similar results have been reported with rats (Beare-Rogers, 1970; Abdellatif and Vles, 1970a, 1970c; Houtsmuller *et al*., 1970) but Rocquelin *et al*. (1970) did not observe any fatty infiltration of liver, heart, and other organs of rats or any differences in their relative weights.

VI. Nutritive value of rapeseed meal for laying chickens

Although numerous experiments have indicated that RSM may be used successfully in rations for laying chickens, recommendation arising from early studies have tended to restrict level of use. Fangauf and Haensel (1938), cited by Jackson (1969), recommended a maximum level of 10% RSM in the rations of layers. Jackson (1969) also quoted the work of Frolich (1952) who reported the performance of layers to decrease with inclusion of 5 and 10% RSM in their rations. O'Neil (1957) obtained results which showed that replacement of all the SBM with RSM in diets that contained some meat and fish meal protein supplements did not affect any criteria of production measured. Clandinin (1962) reported on unpublished data of 1955-56 in which Single Comb White Leghorn (SCWL) pullets were fed rations containing 9% expeller-type RSM in place of SBM without affecting rate of lay over a twenty-four week period. Nevertheless, taking other results into account, it was recommended that not more than 5% RSM be used in laying rations.

More recent studies have indicated some of the adverse effects that may be noted when high levels of RSM were used in laying rations. Sell et al. (1968) observed that the inclusion of RSM in their rations caused a slight but consistent decrease in hen-day production. Egg size was also adversely affected by dietary RSM, while feed consumption and efficiency of feed utilization were not changed appreciably. It was noted that rate of mortality was increased markedly by feeding 10% or more RSM in the ration. Cardin et al. (1968) did not observe any significant reductions in rate of hen-day production, feed consumption, feed conversion and egg size when either pre-press or direct solvent extracted RSM was included in layers' rations up to 16%. They noted however, that the level of mortality of the birds increased as levels of RSM in the diets increased. Kubota and Morimoto (1969) reported that the replacement of 10% SBM by 10% RSM did not adversely affect the egg production, egg weight, feed intake and feed conversion of SCWL hens. In two experiments with laying birds, Clandinin et al. (1972) obtained results which showed that the inclusion of 10% RSM in a laying ration as a replacement for SBM increased mortality, decreased egg production and affected egg size and Haugh unit values to a minor degree. Results of a third experiment, however, showed that the inclusion of 5% or 10% RSM in the ration gave as good results as a SBM control ration.

Some of the variability in results obtained may be related to breed or strain of birds or variety and source of RSM used. Jackson (1969) included various graded levels (0 to 20%) of RSM (Brassica napus) in the rations of two breeds of layers (Hyline-light weight birds and Hybrid 4-medium weight birds). It was observed that while dietary treatment did not significantly affect the death rates of the medium weight birds (Hybrid 4) the light-weight birds (Hyline) exhibited high mortality when fed RSM at a level of 8% or above in the diet. Satisfactory egg production was obtained with 16% RSM in the diet of Hybrid-4 layers while for the Hyline survivors, 8% RSM in the diet resulted in marked reduction in egg production. Total egg weight and mean weight were not affected by dietary treatment. The latter observation was contrary to that of Sell et al. (1968) who found that rations containing 10, 12 and 14% RSM caused a significant decrease in egg size. Jackson (1970) reported that the inclusion of Algerian RSM (from 1.6 to 8%) to diets of SCWL pullets did not have a significant effect on egg production. On all RSM treatments, however, egg production was slightly lower than the control ration containing Peruvian fishmeal as the main source of supplementary protein. With French RSM, Jackson (1970) observed that production decreased slightly with increase in the level of RSM, the highest level of inclusion (8.6%) caused a marked depression in egg production.

The possibility that type of ration or availability of amino acids might affect the utilization of RSM has been suggested. Summers et al. (1969), in a phase feeding experiment involving rations containing protein derived exclusively from plant protein sources, obtained results which indicated that replacing half or all of the SBM with RSM resulted in production of fewer eggs, reduction in egg size and lower weight gain. It was suggested that amino acid balance in RSM rations was a factor influencing the performance of layers fed these rations. With caged layers, Summers et al. (1971) found that at a low level of dietary protein (10%), the addition of RSM to rations of layers to supply one half of the supplementary protein did not significantly affect egg production as compared to that of layers receiving rations in which SBM supplied one half of the supplementary protein. When RSM completely or partially replaced SBM in the ration, at a dietary protein level of 15%, the ration containing RSM gave significantly less egg production, decreased feed intake, caused smaller egg sizes and loss in body weight gain. In general, the higher the level of RSM the less favourable was egg production and egg weight. Since increasing the level of dietary protein from 15% to 16% by increasing the level of RSM from 26.25 to 29%, improved egg production, it was suggested that amino acid availability rather than toxic factors was apparently responsible for the lower performance obtained on the RSM rations. Jackson (1969, 1970) had earlier ruled out the problem of amino acid availability as a factor adversely affecting the egg production of layers fed RSM containing diets.

In addition to the above effects of RSM on egg production traits, the effects of including RSM on some organ characteristics (particularly the thyroid and liver) have been reported. It has been shown that the inclusion of RSM in the rations of layers led to significant increases in thyroid sizes (Kubota and Morimoto, 1969; Cardin et al., 1968; Jackson, 1969, 1970; Summers et al., 1971; Hibino, 1972; Minetoma, 1972). The effect of RSM on liver weight has been variable. Total liver weights of layers were not adversely affected by the inclusion of RSM in their diets (Cardin et al., 1968; Jackson, 1969, 1970). Neither were the relative weights of SCWL layers adversely affected by the inclusion of RSM in their rations (Jackson, 1970). Contrary to the results of Jackson (1970), Minetoma (1972) reported that the relative liver weights of layers fed RSM rations were heavier than those of layers fed a SBM control diet. Minetoma (1972) did not, however, observe any consistent pattern of RSM on liver sizes. Limited studies have shown that the inclusion of RSM in rations of layers did not lead to excessive accumulation of fat in their livers (Jackson, 1969, 1970; Summers et al., 1969).

It was possible, Jackson (1969) postulated, that the fatty livers (about 40% fat in the liver for all groups including the control group) did render the birds more susceptible to the toxic effect of RSM. This was because the main cause of high mortality in his experimental birds was liver haemorrhage. In many other birds, there was evidence of non-fatal liver haemorrhages. Hall (1972), referring back to the report of Jackson (1969), reported the occurrence of an unusual lesion, demonstrated in the livers of laying birds dying from massive, hepatic haemorrhage that caused substantial losses in heavy red breeds of layers in 1971 and 1972. He suggested that, although the cause of the haemorrhage was not known, it was probably due to fatty degeneration, on the basis of the pale, exceptionally friable livers from the affected birds. It was suggested that the condition may be associated with a defect of the reticulin, with the fatal haemorrhage probably occurring when there was a transitory rise in the blood pressure such as when the bird was about to lay an egg rather than to fatty degeneration. It was indicated that the lesion occurred only in birds fed diets containing RSM. Similar conditions in the livers of layers have been reported by Japanese workers (Hiasa, 1972; Minetoma, 1972; Hibino, 1972) all of whom employed Canadian RSM in their experiment. Hibino (1972) was of the view that the liver haemorrhage observed in their birds was probably caused by fatty degeneration of the liver either due to the inclusion of large amounts of fat (tallow) in RSM diets or because of the presence of glucosinolates in RSM. None of the above workers reported on the effect, if any, of RSM on the heart of laying birds, neither did any report on the protein content of the liver, as affected by dietary RSM.

VII. Effects of including unextracted rapeseed and rapeseed oil in rations for laying chickens

Information on the nutritive value of unextracted RS for laying birds is limited. Leslie and Summers (1972) fed unprocessed *Brassica campestris* (Cultivar, Echo) RS at levels of 5, 10 and 15% in rations of

Leghorn-type (Starcross) layers that had been in production for about 10 months. From data collected over a period of 28 days, it was observed that the rations containing 10 to 15% RS depressed production and decreased egg weight. Feed consumption appeared to have been adversely affected particularly by the ration containing 15% RS. On the basis of their results, they recommended that no more than 5% unprocessed RS should be included in the rations of laying birds until more information was obtained.

Since unextracted RS contains about 40% oil, the effect of RSO on performance of layers may be related to the effects of using unextracted RS. Summers _et_ _al_. (1966) reported that the inclusion of 10 or 20% RSO in the rations of 10 months old SCWL pullets stopped production within 7 days. Kondra _et_ _al_. (1968) compared a ration containing 16% RSO with that containing 16% soybean oil. They reported that ration containing RSO resulted in lower hen-day egg production; decreased whole egg and yolk weights; increased Haugh unit values and lower feed consumption. Feed conversion was also adversely affected. Similar results were reported by Walker _et_ _al_. (1970) who noted that the inclusion of 10 or 20% _Brassica_ _campestris_ or _Brassica_ _napus_ RSO in place of the same quantities of tallow or corn oil decreased egg weights. Birds fed ration containing low erucic acid RSO showed significantly higher egg production than those fed RSO containing high erucic acid content. Similar results were recently obtained by Vogtmann _et_ _al_. (1972). Bragg (1969) listed RSO as one of the factors predisposing laying birds to "fatty liver syndrome."

EXPERIMENTS AT THE UNIVERSITY OF ALBERTA

Experiments on the nutritive value of RS and RSM were conducted with broilers and laying hens. The results obtained are reported in the following sections:

Section 1 - Studies on the nutritive value of RS in rations for broiler chicks.

Section 2 - Studies on the use of RSM and of unextracted RS on the productive performance of laying chickens.

SECTION 1

Studies on the nutritive value of RS in rations for broiler chicks.

Status of the Problem

As indicated in the "Introduction", RS with an oil content of approximately 40% and a protein content of 20-23% would appear to be a relatively attractive high energy, high protein ingredient for inclusion in poultry rations. Unfortunately, the presence of glucosinolates in the seed, which may be deleterious to the animal, plus lack of information on the degree to which full-fat RS may be utilized in poultry rations, has limited its use. Consequently, studies were undertaken to evaluate RS as a protein and energy source in rations for broiler chicks. The trials conducted are reported under the following headings:

A. Effects of processing on the nutritive value of RS in rations for broiler chicks - Trials 1 and 2.

B. Effects of amino acid supplementation on the nutritive value of RS for broiler chicks - Trials 3, 4, 5 and 6.

C. Assessment of other factors affecting the nutritive value of RS for broiler chicks - Trials 7 and 8.

Experimental (General)

The proximate composition of samples of Span and Bronowski RS and RSM and of SBM was determined (Table 1) by A.O.A.C. methods (1965).

TABLE 1. - Composition of rapeseed, rapeseed meal and soybean meal.[1]

Ingredients	Moisture %	Protein %	Fat %	Ash %	Fiber[2] %
Bronowski RS	4.9	23.4	39.2	3.3	14.2
Bronowski RSM	7.1	39.4	3.4	5.7	13.9
Span RS	5.9	20.8	39.4	3.8	14.0
Span RSM	9.1	35.1	2.3	6.3	13.9
SBM	8.3	48.8	1.7	6.1	5.8

[1] Values are expressed on an air-dry basis.

[2] Values are expressed on a fat-free, air-dry basis.

A metabolizable energy value of 4400 kcal/kg, based on the metabolizable energy of RSM and RSO, was calculated for full-fat RS. In all trials (except Trials 1 and 2), RS was mixed with wheat before being ground so as to overcome the difficulty encountered when RS is ground alone.

Day-old crossbred (Dominant White x White Plymouth Rock) broiler-type chicks were used in all trials. Forty chicks per treatment, arranged in duplicate or quadriplicate lots, in such a way that the number and mean weights of all lots within a trial were similar, were placed on each treatment. The chicks were wing-banded and brooded in an air-conditioned laboratory in electrically heated batteries with raised screen floors. Continuous lighting was provided. Feed and water were supplied ad libitum.

Individual chick weights were obtained at weekly intervals and feed consumption was determined after 14 days on treatment and at the end of each trial. Feed efficiency was also calculated at the end of each trial. A record of mortality was kept. The trials were terminated when the chicks were 4 weeks old. In each trial, the rations were analysed for crude protein, ether extract (fat) and dry matter content by A.O.A.C. methods (1965).

At the conclusion of the experiments, the data were subjected to analyses of variance and significance of differences were assessed by applying Duncan's Multiple Range Test (Steel and Torrie, 1960) at the 0.05 level of probability. Details of the analyses of variance are presented in appendix III to VI.

A. Effects of processing on the nutritive value of rapeseed in rations for broiler chicks

Status of the Problem

The presence of glucosinolates in RS may have adverse effects on animals to which the seed is fed. It therefore seemed desirable to try to develop methods of processing that would improve the nutritive value of full-fat RS.

Since procedures have been developed that result in the production of high quality RSM following commercial processing to remove the oil from RS, it seemed possible that some of the methods might be adapted to improve the quality of unextracted RS.

Trial 1

Object

The object of the first trial was to assess the effect of application of heat treatment or extraction with solvents on the nutritive value and goitrogenicity of RS.

Experimental

Three hundred and twenty day-old broiler-type chicks of mixed sexes were used in this trial. The chicks were divided into 16 lots of 20 chicks each and two lots were placed on each experimental ration.

The composition of the basal rations used (Basals 1, 2 and 4) is shown in Table 2. The rations used were isocaloric and isonitrogeneous.

The treatments used are outlined in Table 3. RS treated in various ways was included in the ration at a level of 10%. The

TABLE 2. - Composition of basal rations - Trials 1 and 2.

Ingredients	Basal ration number				
	1 Control ration	2 10% RS	3 20% RS	4 5% RSM	5 5% RSM + 5% RSO
	%	%	%	%	%
Ground wheat (13.0% protein)	58.97	56.22	48.22	56.72	57.72
Soybean meal (48.5% protein)	31.00	27.25	26.25	27.25	27.25
Whole rapeseed (21.0% protein)	-	10.00	20.00	-	-
Rapeseed meal (37.0% protein)	-	-	-	5.00	5.00
Rapeseed oil	-	-	-	-	5.00
Stabilized tallow	5.00	1.50	0.50	6.00	-
Dehydrated alfalfa	1.00	1.00	1.00	1.00	1.00
Ground limestone (38.0% Ca)	1.75	1.75	1.75	1.75	1.75
Calcium phosphate (18.5% Ca; 20.5 P)	1.50	1.50	1.50	1.50	1.50
Premix[1]	0.50	0.50	0.50	0.50	0.50
Iodized salt (150 ug I/kg)	0.25	0.25	0.25	0.25	0.25
Manganese oxide (62% Mn)	0.02	0.02	0.02	0.02	0.02
Zinc oxide (78.5% Zn)	0.01	0.01	0.01	0.01	0.01
Composition					
Protein (%) calculated	23.0	22.9	23.4	22.9	22.9
Protein (%) analysed	23.8	23.9	24.4	23.8	23.8
Fat (%) analysed	6.5	6.5	9.6	7.6	6.3
Dry matter (%) analysed	88.8	89.0	88.7	88.8	88.9
Calcium (%) calculated	1.02	1.02	1.04	1.02	1.02
Total Phosphorus (%) calculated	0.75	0.76	0.79	0.76	0.76
M.E.[2] kcal/kg diet, calculated	3000	3000	3100	3000	3000

[1] Supplied per kg ration: vitamin A, 4000 I.U.; vitamin D_3, 400 I.C.U.; vitamin E, 20 I.U.; vitamin K, 2 mg; riboflavin, 5 mg; calcium pantothenate, 10 mg; niacin, 20 mg; choline choride, 200 mg; vitamin B_{12}, 10 μg; folic acid, 2 mg; amprolium, .125 g; furazolidone, 0.11 g; and DL-methionine, 0.5 g.

[2] ME = metabolizable energy.

TABLE 3. - Effects of processing of rapeseed on weight gain, feed conversion and thyroid weight of chicks.

Group No.	Dietary treatment	Wt gain[1] g	Feed conversion g feed / g gain	Thyroid wt. mg/100g body wt
1.	Control ration	514^{a}	1.73	9.2^{ab}
2.	10% RS (raw)	444^{b}	1.90	13.4^{bc}
3.	10% RS (oven-heated 30 min @ 105C)	447^{b}	1.91	13.0^{abc}
4.	10% RS (oven-heated 30 min @ 110C)	428^{b}	1.93	13.3^{bc}
5.	10% RS (acetone-water extracted)	450^{ab}	1.79	12.1^{ab}
6.	10% RS (hot water treated)	470^{ab}	1.83	11.8^{ab}
7.	10% RS (autoclaved 10 min @ 120C)	465^{ab}	1.89	8.4^{a}
8.	5% RSM	486^{ab}	1.86	17.2^{c}
	SEM*	18	0.04	1.4

[1] Column values with same superscript or no superscript are not significantly different ($P < 0.05$).

* SEM = Standard error of means.

treatments used included heating in an oven for 30 minutes at 105C or 110C; extracting the seed with a mixture of acetone and water (4:1) for 2 hours followed by removal of the solvent by centrifuging; dipping the seed into boiling water for 10 minutes followed by decantation and drying in the oven at 50C for 3 hours; autoclaving at 120C for 10 minutes in shallow trays filled to a depth of about an average of 1 seed per unit area followed by air-drying by spreading the seed on a plastic sheet at room temperature (22C) for 10-12 hours.

At the conclusion of the trial when the birds were 4 weeks old, 4 chicks from each experimental group were killed by cervical dislocation, and the thyroid glands were removed and weighed. Thyroid-to-body weight-ratios(relative thyroid weight)were then calculated.

Results and Discussion

The results obtained in this trial are summarized in Table 3.

Inclusion of 10% raw RS in the ration resulted in a significant decrease in the rate of growth of chicks as compared to those fed the control ration containing SBM (Group 2 vs. 1). The thyroid-to-body weight ratios of chicks fed the ration containing ground raw RS were increased by approximately 50%. Oven-heating; acetone-water extraction; hot water treatment; or autoclaving at 120C for 10 minutes did not result in any significant improvement in weight gain or efficiency of feed conversion as compared to the use of untreated RS. It was noted however, that when RS was autoclaved at 120C for 10 minutes (Group 7), relative thyroid weight was not increased above that noted in the chicks fed the control ration (Group 1). Thus autoclaving appeared to be the most desirable treatment to use in subsequent experiments.

Performance of chicks fed the ration containing 5% commercial RSM (Group 8) was not significantly different from that of chicks receiving the ration containing 10% autoclaved RS (Group 7). The thyroid to body weight ratios of this group (Group 8) were however significantly higher than those of chicks fed the control ration (Group 1) or ration containing 10% autoclaved RS (Group 7).

Summary

A trial was conducted to assess the effect of application of heat or extraction with solvents on the nutritive value and goitrogenecity of RS. The results obtained indicated the following:

1. Inclusion of raw RS in the ration of chicks resulted in a significant decline in growth rates of chicks and also caused enlargement of the thyroid glands.
2. None of the processing techniques used significantly improved growth rates and efficiency of feed conversion of chicks beyond those obtained for chicks fed a ration containing 10% raw RS.
3. Autoclaving RS before inclusion in the ration significantly reduced the goitrogenicity of RS as determined by the reduced thyroid-to-body weight ratios of chicks fed ration containing 10% autoclaved RS.

Trial 2

Object

Since heating RS in the autoclave at 120C for 10 minutes appeared to reduce its goitrogenicity, a trial was conducted to study the effect of autoclaving time (10 or 5 minutes) and level of use of

RS (10 or 20%) on the nutritive value of full-fat RS.

Experimental

The experimental procedure used was similar to that used in Trial 1 except that a low erucic acid Brassica campestris variety (Cultivar, Span) was used. The composition of the basal rations (Basals 1 to 5) used is shown in Table 2.

Results and Discussion

The treatments used and the results obtained in this trial are summarized in Table 4. Inclusion of raw RS in the ration significantly depressed rates of growth of chicks as compared to those of chicks fed the control ration containing SBM (Group 2 vs. 1). Autoclaving the RS for 10 minutes at 120C before inclusion at the 10% level in the ration slightly improved the growth rates of chicks and tended to decrease relative thyroid weights (Group 3 vs. 2). Inclusion of the heated seed at 20% of the ration resulted in a lower rate of growth than was obtained when 10% was used (Groups 4 and 6 vs. Groups 3 and 5, respectively). When length of autoclaving time was reduced from 10 to 5 minutes, rate of growth was decreased and relative thyroid weights tended to be larger (Groups 5 and 6 vs. 3 and 4, respectively). The performance of groups of chicks fed rations containing 5% commercial RSM and either tallow or RSO (Groups 7 and 8) was not significantly different from that of chicks receiving 10% autoclaved RS (Group 3). It was noted however that, while the growth rates of chicks receiving 5% commercial RSM plus stabilized tallow (Group 7) was not significantly different from that of chicks receiving the control ration (Group 1), growth rate of chicks receiving 5% commercial RSM

TABLE 4. - Effects of time of autoclaving and level of rapeseed on weight gain, feed conversion and thyroid weight of chicks.

Group No.	Dietary treatment	Wt gain[1] g	Feed conversion $\frac{\text{g feed}}{\text{g gain}}$	Thyroid wt mg/100g body wt
1.	Control ration	511^{a}	1.69	6.6
2.	10% RS (raw)	448^{cd}	1.80	12.0
3.	10% RS (autoclaved 10 min @ 120C)	470^{bc}	1.80	9.0
4.	20% RS (autoclaved 10 min @ 120C)	425^{d}	1.85	9.7
5.	10% RS (autoclaved 5 min @ 120C)	419^{d}	1.83	11.4
6.	20% RS (autoclaved 5 min @ 120C)	387^{e}	1.82	11.7
7.	5% RSM plus stabilized tallow	495^{ab}	1.67	9.0
8.	5% RSM plus RSO	465^{bc}	1.73	7.7
	SEM	10	0.05	1.6

[1] Column values with same superscript or no superscript are not significantly different ($P<0.05$).

plus RSO was significantly below that of chicks receiving the control ration (Group 8 vs. 1).

In this trial, relative thyroid weights showed considerable variability and none of the differences were found to be statistically significant.

Summary

A trial was conducted to study the effect of length of autoclaving time and level of usage of RS in the ration on the nutritive value of RS. The results obtained indicated the following:

1. Inclusion of 10% raw RS in the ration significantly depressed the growth rates of chicks as compared to those fed the control ration.
2. Increasing the level of autoclaved RS from 10 to 20% of the ration or decreasing the length of time the RS was autoclaved resulted in a reduction of growth rates of chicks.
3. The inclusion of 5% commercial RSM plus stabilized tallow in the ration resulted in growth rates similar to those of chicks fed the control ration. The replacement of stabilized tallow by RSO tended to decrease growth rates of chicks.

B. Effects of amino acid supplementation on the nutritive value of rapeseed for broiler chicks

Status of the Problem

Although the quality of RS was improved by autoclaving at 120C for 10 minutes, the level of growth attained when autoclaved RS was used was generally lower than growth obtained on the control ration. In considering reasons for this, it seemed possible that the difference could have been related to the balance of amino acids in the ration. Consequently, studies were undertaken to determine the effects of amino acid supplementation of broiler rations containing RS.

Trial 3

Object

To study the effects of supplementing rations containing autoclaved Span RS with the amino acids which were most limiting in the ration.

Experimental

Male chicks were used in this trial. They were wing-banded at day-old and maintained in the battery for a pre-test period (0-6 days post-hatching) during which they were fed the control ration (Basal 6, Table 5). After an overnight fast, they were individually weighed and assigned to lots of 20 birds each on the basis of weight so that the average starting weight and weight range were similar in each lot. Two lots were randomly assigned to each treatment (Table 6). Other management factors were the same as those in "Experimental (General)" and in Trials 1 and 2. The experiment was terminated after 3 weeks on treatment.

The composition of the basal rations (Basals 6, 7 and 9) is shown in Table 5. The experimental treatment used, showing the type and levels of amino acid supplementation used, are outlined in Table 6. Amino acid additions were made by replacing isonitrogenous amounts of glutamic acid and by adjusting the level of corn starch in the rations in such a manner that all rations remained isocaloric and isonitrogenous.

The amino acids added were selected on the basis of calculated analysis of rations. The amino acid content of Span, Bronowski RS and RSM and of SBM were determined (Table 7). Analyses were conducted on 6N HCl hydrolysates (prepared in duplicate) of 1 gram meal samples using

TABLE 5. - Composition of basal rations - Trials 3 and 4.

Ingredients	Basal ration number			
	6 Control ration %	7 10% RS %	8 20% RS %	9 5% RSM %
Ground wheat (13.0% protein)	59.00	56.00	48.00	56.00
Soybean meal (48.5% protein)	29.25	25.75	24.75	26.25
Whole rapeseed (21.0% protein)	-	10.00	20.00	-
Rapeseed meal (37.0% protein)	-	-	-	5.00
Stabilized tallow	5.00	1.50	0.50	6.00
Dehydrated alfalfa	1.00	1.00	1.00	1.00
Ground limestone (38.0% Ca)	1.75	1.75	1.75	1.75
Calcium phosphate (18.5% Ca; 20.5 P)	1.50	1.50	1.50	1.50
Premix[1]	0.50	0.50	0.50	0.50
Iodized salt (150 ug I/kg)	0.25	0.25	0.25	0.25
Manganese oxide (62% Mn)	0.02	0.02	0.02	0.02
Zinc oxide (78.5% Zn)	0.01	0.01	0.01	0.01
Glutamic acid	1.35	1.35	1.35	1.35
Cornstarch	0.37	0.37	0.37	0.37
Composition				
Protein (%) calculated	22.9	22.9	23.5	22.9
Protein (%) analysed	23.8	23.8	24.1	23.7
Fat (%) analysed	6.8	6.8	9.4	8.4
Dry matter (%) analysed	91.1	90.9	91.3	91.0
Calcium (%) calculated	1.02	1.02	1.03	1.02
Total Phosphorus (%) calculated	0.74	0.75	0.76	0.75
M.E.kcal/kg diet[2], calculated	2975	2975	3072	2975
M.E.kcal/kg diet[3], calculated	3023	3023	3120	3023

[1] See Table 2 for composition of premix.

[2] Calculated without considering energy contribution by glutamic acid.

[3] Calculated considering energy value of glutamic acid to be 3.65 kcal/g

TABLE 6. - Effects of amino acid supplementation of rations containing autoclaved rapeseed on average weight gain, feed conversion and thyroid weights of chicks.

Group No.	Dietary level (%) and type of RS	Amino acid supplements[2]	Wt gain[3] g	Feed conversion g feed / g gain	Thyroid wt mg/100g body wt
1	0 (Control ration)	-	449^{ab}	1.82	9.5
2	10 (raw)	-	394^{c}	1.96	12.7
3	10 (autoclaved)[1]	-	422^{b}	1.89	8.5
4	10 (autoclaved)	0.2% arg.	446^{ab}	1.88	8.8
5	10 (autoclaved)	0.2% lys.	428^{ab}	1.86	9.4
6	10 (autoclaved)	0.1% meth.	441^{ab}	1.86	9.4
7	10 (autoclaved)	0.2% arg. + 0.2% lys.	439^{ab}	1.90	6.8
8	10 (autoclaved)	0.2% arg. + 0.1% meth.	456^{a}	1.80	8.1
9	10 (autoclaved)	0.2% lys. + 0.1% meth.	443^{ab}	1.86	9.9
10	10 (autoclaved)	0.2% lys. + 0.2% arg. + 0.1% meth.	430^{ab}	1.86	9.9
11	10 (autoclaved)	AS 10 + 0.2% threo. + 0.5% hist. + 0.05% try.	441^{ab}	1.86	8.7
12	5% RSM		448^{ab}	1.80	9.0
	SEM		9	0.03	1.1

[1] Rapeseed referred to as autoclaved was heated in the autoclave for 10 minutes at 120C.

[2] The following abbreviations for amino acids are used: arg. (L-arginine); lys. (L-lysine); meth. (DL-methionine); threo. (DL-threonine); hist. (L-histidine); try. (L-tryptophan).

[3] Column values with same superscripts or no superscripts are not significantly different ($P<0.05$).

TABLE 7 - Amino acid composition of rapeseed, commercial rapeseed meal and soybean meal.[1]

	Span RS[2] %	Span RSM[3] %	Bronowski RS %	Bronowski RSM %	SBM %
Ammonia	2.29	2.24	2.38	2.14	1.86
Alanine	4.48	4.52	4.20	4.22	4.30
Arginine	5.81	5.82	6.53	6.19	7.08
Aspartic acid	7.16	7.18	6.84	6.87	11.60
Cystine	2.14	1.87	2.70	2.90	1.75
Glutamic acid	18.02	18.06	18.41	17.82	18.46
Glycine	5.10	5.07	4.91	4.96	4.25
Histidine	2.96	2.84	3.00	2.82	2.54
Isoleucine	3.89	4.00	3.72	3.83	4.58
Leucine	6.71	6.92	6.48	6.69	7.76
Lysine	6.46	6.24	6.48	5.85	6.12
Methionine	1.96	1.96	1.66	1.71	1.28
Phenylalanine	4.21	3.96	3.95	4.00	5.11
Proline	7.04	6.46	6.37	6.20	5.27
Serine	4.40	4.50	4.24	4.25	5.19
Threonine	4.51	4.60	4.21	4.23	3.98
Tyrosine	2.44	2.48	2.34	2.36	3.23
Valine	5.25	5.18	4.90	5.03	4.88

[1] Values are expressed as a percentage of protein (N x 6.25) on an air-dry, fat-free basis.

[2] Raw and autoclaved rapeseed gave similar amino acid values.

[3] RSM = rapeseed meal.

TABLE 7 (continued) - Essential amino acid composition of experimental rations[1] as compared to N.R.C. (1971) requirements for chicks.

	Control ration %	10% RS %	20% RS %	N.R.C. (1971) %
Amino acids				
Methionine	0.43	0.43	0.44	0.46
Cystine	0.31	0.30	0.31	0.40
Arginine	1.33	1.32	1.35	1.40
Lysine	1.13	1.13	1.19	1.25
Threonine	0.77	0.79	0.83	0.80
Tryptophan	0.28	0.29	0.29	0.23
Histidine	0.48	0.48	0.51	0.46
Glycine	1.33	1.31	1.32	1.15
Leucine	1.69	1.68	1.71	1.60
Isoleucine	1.25	1.21	1.21	0.86
Valine	1.19	1.18	1.20	1.00
Phenylalanine	1.22	1.19	1.18	0.80
Tyrosine	0.71	0.69	0.69	0.70

[1] Calculated analysis (as a percentage of the ration).

a Technicon Amino Acid Analyser. The caluclated amino acid composition of the basal rations used is shown in Table 7.

Results and Discussion

The results obtained (Table 6) indicated that inclusion of 10% raw RS in the ration significantly depressed growth rates of chicks as compared to those of chicks fed the control ration (Group 2 vs. 1). Growth rates of chicks fed the ration containing 10% autoclaved RS were significantly higher than those of chicks fed the ration containing 10% raw RS (Group 3 vs. 2).

The addition of 0.2% L-arginine and 0.1% DL-methionine, alone (Groups 4 and 6) or in combination (Group 8) to the ration containing 10% autoclaved RS resulted in rates of growth and feed efficiency equivalent to those obtained on the control ration (Group 1) and the combination of 0.2% arginine and 0.1% methionine gave growth rates that were significantly higher than those obtained with the unsupplemented ration (Group 8 vs. 3). The addition of 0.2% L-lysine, alone (Group 5) or in various combinations with arginine and methionine (Groups 7, 9 and 10) had no additional effect on growth rate or feed efficiency. Inclusion of threonine, histidine and tryptophan, in addition to supplemental arginine, lysine and methionine (Group 11) also had no effect on rate of growth, feed efficiency or relative weights of the thyroids. The inclusion of 5% RSM in the ration (Group 12) resulted in chick performance similar to that obtained on the control ration (Group 1) and on the ration containing 10% autoclaved RS (Group 3).

Dietary treatments had no significant effect on feed efficiency or relative thyroid weights. Rations containing autoclaved RS, however, tended to give lower relative thyroid weights than were obtained on the ration containing raw RS.

Summary

A trial was conducted to study the effects of supplementing rations containing autoclaved RS with certain amino acids. The results obtained indicated the following:

1. Inclusion of 10% raw RS in the ration resulted in a significant decline in rate of growth. When 10% autoclaved RS was included in the ration, growth rate was significantly improved and was not significantly different from that obtained on the control ration.
2. The addition of 0.2% L-arginine and 0.1% DL-methionine, alone or in combination, to the ration containing 10% autoclaved RS improved the growth rates of chicks.
3. Inclusion of lysine, alone or in various combinations with arginine and methionine, had no additional effect on performance of chicks; neither did the inclusion of threonine, histidine and tryptophan, in addition to supplemental arginine, lysine and methionine.
4. Dietary treatments used had no significant effect on feed efficiency or relative thyroid weights of the chicks.

Trial 4

Object

To study the effect of inclusion of 2 levels of RS (10 and 20%); 2 levels of supplemental methionine (0.1 and 0.2%) and 1 level of supplemental arginine (0.2%) on the performance of broilers. The study included determination of the effect of treatment on the relative weights of some organs, other than the thyroid, and on carcass composition.

Experimental

The experimental methods used in this trial were the same as described in Trial 3. The composition of the basal rations used (Basals 6, 7 and 8) is shown in Table 5. Span RS was used at levels of 10 and 20%.

At the end of the experimental period, after an overnight fast, thyroids, heart (myocardium), liver, pancreas, spleen and testes from 4 chicks per group were removed, weighed immediately and their weight relative to body weight was calculated. In addition, the carcasses of 4 chicks per group were analysed individually for percentage dry matter, protein and fat as described in Appendix 1.

Results and Discussion

The effects of the dietary treatments on average weight gain, feed conversion and relative thyroid weights are summarized in Table 8.

Inclusion of 10% raw RS in the ration of chicks (Group 2) resulted in a significant decline in rate of growth as compared to that of chicks fed the control ration (Group 1). Increasing the level of raw RS to 20% (Group 3) resulted in a further significant decline in rate of growth. When 10 or 20% autoclaved RS was included (Groups 4 and 5) growth rate was improved as compared to that of chicks fed the rations containing 10 or 20% raw RS (Groups 2 and 3). The improvement in growth rate due to autoclaving was significant when the rations containing 20% RS are compared (Group 5 vs. 3). Growth rates of chicks fed ration containing 10 or 20% autoclaved RS (Groups 4 and 5) were however still significantly lower than those of chicks fed the control

TABLE 8. - Effects of amino acid supplementation of rations containing autoclaved rapeseed on average weight gain, feed conversion and thyroid weight of chicks.

Group No.	Dietary level (%) and type of RS	Amino acid supplements[2]	Wt gain[3] g	Feed conversion g feed / g gain	Thyroid wt mg/100g body wt
1	0 (Control ration)	-	449^{a}	1.75^{a}	7.5^{a}
2	10 (raw)	-	393^{c}	1.92^{b}	15.9^{d}
3	20 (raw)	-	293^{d}	2.14^{c}	16.0^{d}
4	10 (autoclaved)[1]	-	412^{bc}	1.86^{ab}	11.1^{abc}
5	20 (autoclaved)	-	408^{bc}	1.84^{ab}	11.9^{bcd}
6	10 (autoclaved)	0.1% meth.	417^{bc}	1.77^{a}	10.6^{abc}
7	10 (autoclaved)	0.2% meth.	418^{bc}	1.85^{ab}	8.1^{ab}
8	20 (autoclaved)	0.1% meth.	417^{bc}	1.87^{ab}	12.8^{cd}
9	20 (autoclaved)	0.2% meth.	428^{ab}	1.80^{ab}	12.8^{cd}
10	10 (autoclaved)	0.1% meth. + 0.2% arg.	449^{a}	1.76^{a}	10.1^{abc}
11	20 (autoclaved)	0.1% meth. + 0.2% arg.	431^{ab}	1.84^{ab}	12.0^{bcd}
12	20 (autoclaved)	0.2% meth. + 0.2% arg.	418^{bc}	1.86^{ab}	9.1^{abc}
	SEM		8	0.04	1.3

[1] Heated in the autoclave for 10 minutes at 120C.

[2] Meth. = DL-methionine; arg. = L-arginine.

[3] Column values with same superscript are not significantly different ($P<0.05$).

ration (Group 1). In this trial, the addition of either 0.1 or 0.2% methionine to the rations containing 10 or 20% autoclaved RS did not significantly affect rate of growth (Groups 6 to 9 vs. 4 and 5). The simultaneous addition of 0.1% methionine and 0.2% arginine (Groups 10 and 11), however, gave growth rates similar to those obtained on the control ration (Group 1). At the 10% level of inclusion of autoclaved RS, the simultaneous addition of 0.1% methionine and 0.2% arginine significantly improved rates of growth over that obtained with the unsupplemented ration (Group 10 vs. Group 4).

In this trial, the use of raw RS at either the 10 or 20% level resulted in increased feed requirement per unit of gain and an approximate doubling in relative weight of the thyroid (Groups 2 and 3 vs. 1). When autoclaved RS was used (Groups 4 and 5), feed conversion was essentially equivalent to that noted on the control ration (Group 1) and goitrogenicity was reduced as compared to that noted when raw RS was used (Groups 2 and 3).

Data on relative weights of the other organs that were determined are shown in Table 9. No significant effect of treatment on the relative weights of testes, spleens, or pancreas was noted. Small but significant differences in the relative weights of hearts and livers were noted in some groups but no pattern was noted that could explain the differences.

Dietary treatment had a significant effect on the dry matter content of the carcasses (Table 10). There were also some effects on the protein and fat contents. Inclusion of raw RS in the ration resulted in significantly lower percentage carcass dry matter and leaner carcasses (lower percentage carcass fat, expressed on a dry

TABLE 9. - Effects of amino acid supplementation of rations containing autoclaved rapeseed on relative organ weights of chicks.

Group No.	Dietary level(%) and type of RS	Amino acid supplements^2	Organ weights^3				
			Testes^4	Spleen	Pancreas	Heart	Liver
1	0 (Control ration)	-	0.023	0.126	0.286	0.542^{a}	3.20^{ab}
2	10 (raw)	-	0.024	0.147	0.331	0.601^{abcd}	2.88^{a}
3	20 (raw)	-	0.023	0.108	0.330	0.688^{cd}	3.68^{ab}
4	10 (autoclaved)^1	-	0.020	0.160	0.307	0.612^{abcd}	2.81^{a}
5	20 (autoclaved)	-	0.027	0.126	0.313	0.576^{ab}	3.70^{ab}
6	10 (autoclaved)	0.1% meth.	0.020	0.128	0.308	0.555^{a}	3.45^{ab}
7	10 (autoclaved)	0.2% meth.	0.019	0.116	0.309	0.588^{abc}	4.39^{c}
8	20 (autoclaved)	0.1% meth.	0.020	0.142	0.310	0.603^{abcd}	3.99^{b}
9	20 (autoclaved)	0.2% meth.	0.017	0.125	0.329	0.654^{bcd}	3.64^{ab}
10	10 (autoclaved)	0.1% meth. + 0.2% arg.	0.021	0.135	0.343	0.571^{ab}	3.42^{ab}
11	20 (autoclaved)	0.1% meth. + 0.2% arg.	0.021	0.125	0.285	0.587^{abc}	4.03^{b}
12	20 (autoclaved)	0.2% meth. + 0.2% arg.	0.019	0.119	0.277	0.694^{d}	3.47^{ab}
	SEM		0.000	0.017	0.020	0.031	0.45

[1] Heated in the autoclave for 10 minutes at 120C.

[2] Meth. = DL-methionine; arg. = L-arginine.

[3] Expressed in g/100 g body weight.

[4] Column values with same superscript or no superscript are not significantly different ($P<0.05$).

TABLE 10. - Effects of amino acid supplementation of rations containing autoclaved rapeseed on carcass composition of chicks.

Group No.	Dietary level (%) and type of RS	Amino acid supplements[2]	Carcass Dry matter[3] %	Carcass Fat[4] %	Carcass Protein[4] %
1	0 (Control ration)	-	33.8^{a}	34.7^{a}	55.5
2	10 (raw)	-	30.4^{bc}	21.7^{c}	64.2
3	20 (raw)	-	30.7^{bc}	23.5^{c}	64.0
4	10 (autoclaved)[1]	-	32.3^{abc}	26.9^{bc}	59.0
5	20 (autoclaved)	-	31.9^{ab}	27.0^{bc}	59.8
6	10 (autoclaved)	0.1% meth.	31.5^{abc}	27.2^{bc}	59.6
7	10 (autoclaved)	0.2% meth.	32.2^{abc}	25.5^{bc}	59.2
8	20 (autoclaved)	0.1% meth.	30.4^{bc}	26.0^{bc}	62.1
9	20 (autoclaved)	0.2% meth.	31.8^{ab}	25.2^{bc}	59.3
10	10 (autoclaved)	0.1% meth. + 0.2% arg.	32.5^{ab}	30.6^{ab}	56.8
11	20 (autoclaved)	0.1% meth. + 0.2% arg.	30.9^{bc}	23.2^{c}	60.8
12	20 (autoclaved)	0.2% meth. + 0.2% arg.	30.1^{c}	25.3^{bc}	64.0
	SEM		0.7	1.9	1.9

[1] Heated in the autoclave for 10 minutes at 120C.

[2] Meth. = DL-methionine; arg. = L-arginine.

[3] Column values with same superscript or no superscript are not significantly different ($P < 0.05$).

[4] Values are expressed on a dry matter basis.

matter basis), than those noted on the control ration (Groups 2 and 3 vs. 1). Inclusion of autoclaved RS in the ration (Groups 4 and 5) led to carcass composition that fell midway between the carcass composition of chicks fed the control ration (Group 1) and those fed raw RS in their rations (Group 2 and 3). Addition of methionine and arginine, alone or in combination, had no appreciable effect on the carcass composition (Groups 6 to 12).

In general, all rations containing RS produced leaner carcasses than those produced by the control ration. Except for one case (Group 10), all rations containing RS produced carcasses with significantly lower percentage carcass fat than those produced on the control ration. The higher percentage carcass protein obtained for chicks fed rations containing RS approached significance.

Summary

Rations containing either 10 or 20% RS or autoclaved RS rations supplemented with methionine or arginine were fed to chicks from 1 to 4 weeks of age. The results obtained indicated the following:

1. Inclusion of 10 or 20% autoclaved RS in place of raw RS in the ration resulted in improved growth rates, feed conversion and lower relative thyroid weights.
2. Rations containing autoclaved RS were nutritively improved by the simultaneous addition of 0.1% methionine and 0.2% arginine.
3. Inclusion of RS in the rations did not significantly affect the relative weights of the testes, spleens and pancreas. No pattern could be perceived to explain the small but significant differences in the heart and liver relative weights that were

obtained with some groups.

4. Rations containing raw RS produced leaner carcasses than the control ration. Inclusion of autoclaved RS in the ration led to carcass composition that fell midway between that of chicks fed the control ration and that of chicks fed rations containing raw RS.

Trial 5

Object

To study the effects on growth rates, feed conversion efficiency, relative organ weights (thyroids, liver and heart), carcass, liver and heart composition, of supplementing rations containing RS with different levels of arginine (0.1, 0.2 and 0.3%).

Experimental

The same experimental technique employed in Trials 3 and 4 was used in this trial. Span RS was included at the 20% level and the control ration was modified to make it isocaloric and isonitrogenous with the rations containing 20% RS. Three levels of arginine (0.1, 0.2 and 0.3%) were tested with the rations containing autoclaved RS while one level (0.2%) of arginine was tested with the ration containing raw RS. The composition of the basal rations (Basals 10 and 11) used in this trial is shown in Table 11. All rations were kept isonitrogenous and isocaloric by varying the levels of corn starch and glutamic acid in the rations.

The thyroids, liver and heart from 4 chicks per experimental group were removed and treated as described in Trial 4. In addition, the liver and heart so removed were stored at -30°C and later individually analysed for gross composition of percentage dry matter, protein

TABLE 11. - Composition of basal rations - Trial 5.

Ingredients	Basal ration number 10 Control ration %	 11 20% RS %
Ground wheat (13.0% protein)	54.00	48.00
Soybean meal (48.5% protein)	31.75	24.75
Whole rapeseed (21.0% protein)	-	20.00
Stabilized tallow	7.50	0.50
Dehydrated alfalfa	1.00	1.00
Ground limestone (38.0% Ca)	1.75	1.75
Calcium phosphate (18.5% Ca; 20.5 P)	1.50	1.50
Premix[1]	0.50	0.50
Iodized salt (150 ug I/kg)	0.25	0.25
Manganese oxide (62% Mn)	0.02	0.02
Zinc oxide (78.5% Zn)	0.01	0.01
Glutamic acid	1.35	1.27
Cornstarch	0.37	0.35
DL-methionine	-	0.10
Composition		
Protein (%) calculated	23.5	23.5
Protein (%) analysed	23.8	23.8
Fat (%) analysed	9.4	10.4
Dry matter (%) analysed	91.1	90.8
Calcium (%) calculated	1.01	1.03
Total Phosphorus (%) calculated	0.74	0.76
ME. kcal/kg diet, calculated	3120	3120

[1] See Table 2 for composition of premix.

and fat as described in Appendix 1. Four chicks per experimental group were also selected as in Trial 4, and body composition was determined by the procedure described in Appendix 1.

Results and Discussion

The effects of treatment on average weight gain, feed conversion and relative organ weights are summarized in Table 12.

As in Trial 4, inclusion of 20% raw RS in the ration significantly depressed growth rates of chicks as compared to those of chicks fed the control ration (Group 2 vs. 1). When 20% autoclaved RS was included in the ration (Group 4), growth rate was significantly improved as compared to that of chicks receiving the ration containing raw RS (Group 2) but was still significantly lower than that obtained on the control (Group 1). None of the levels of arginine used improved growth rates significantly although the inclusion of 0.2% arginine to the 20% autoclaved RS ration resulted in a rate that was not significantly different from that of the control ration (Group 6 vs. 1).

The use of 20% raw RS resulted in increased feed requirement per unit gain and about 50% increase in relative weights of the thyroids of chicks as compared to those obtained on the control ration (Group 2 vs. 1). When 20% autoclaved RS was used, feed conversion and relative thyroid weights were essentially equivalent to those noted on the control ration (Group 4 vs. 1). Addition of arginine to the rations had no significant effect on the feed conversion or thyroid-to-body weight ratios.

None of the treatments used had any significant effect on the relative weights of livers or hearts. The effects exerted on the

TABLE 12. - Effects of varying levels of arginine on the average weight gain, feed conversion and organ weights of chicks.

Group No.	Dietary treatment	Wt gain[4] g	Feed conversion $\frac{\text{g feed}}{\text{g gain}}$	Thyroid wt mg/100g body wt	Liver wt g/100g body wt	Heart wt g/100g body wt
1	Control ration	451^{a}	1.80^{a}	10.6	2.15	0.540
2	20% RS[1] (raw)	348^{d}	2.00^{b}	14.9	2.53	0.582
3	20% RS (raw) + 0.2% arg.[2]	355^{d}	2.04^{b}	15.5	2.59	0.567
4	20% RS (autoclaved)[3]	432^{bc}	1.82^{a}	11.8	2.40	0.532
5	20% RS (autoclaved) + 0.3% arg.	430^{bc}	1.80^{a}	10.8	2.44	0.495
6	20% RS (autoclaved) + 0.2% arg.	438^{abc}	1.80^{a}	8.2	2.33	0.490
7	20% RS (autoclaved) + 0.1% arg.	425^{c}	1.77^{a}	13.5	2.35	0.545
	SEM	3	0.04	1.3	1.43	0.039

[1] All RS rations contained additional 0.01% DL-methionine.

[2] arg. = L-arginine.

[3] Heated in the autoclave for 10 minutes at 120C.

[4] Column values with same superscript or no superscript are not significantly different ($P < 0.05$).

relative thyroid weights approached significance.

The effects of treatments on carcass composition (Table 13) followed a similar trend as in Trial 4. Although there were no significant differences in percentage dry matter content among the groups, all rations containing RS produced leaner carcasses than the control ration. Inclusion of raw RS in the ration (Group 2) resulted in significantly higher percentage carcass protein and lower percentage carcass fat as compared to those obtained with the control ration (Group 1) or the ration containing autoclaved RS (Group 4). The addition of arginine to the rations did not exert any significant effect on the carcass composition.

Data on heart and liver composition are also summarized in Table 13. Composition of the hearts tended to vary in a manner similar to that noted for carcass composition. Including RS in the ration fed, resulted in hearts with higher percentage protein content and lower percentage fat content than was obtained when the control ration was fed. The differences in percentage dry matter content of the hearts were not significant. None of the dietary treatments employed exerted a significant effect on the percentage dry matter and protein content of the liver, but some significant differences occurred in the fat content of the livers. The differences observed did not appear to be large enough to be of real practical significance; since the fat content of the liver on all rations containing autoclaved RS (Groups 4 to 7) was lower than that of the control ration. The chicks receiving the ration containing raw RS (Group 2) had liver fat levels similar to those observed on the control ration (Group 1).

TABLE 13. - Effects of varying levels of arginine on carcass, heart and liver composition of chicks.

Group No.	Dietary treatment	Carcass			Heart			Liver		
		Dry matter[4] %	Fat[5] %	Protein[5] %	Dry matter %	Fat[5] %	Protein[5] %	Dry matter %	Fat[5] %	Protein[5] %
1	Control ration	31.3	27.3^{a}	61.5^{a}	25.1	23.2	60.8^{a}	27.6	11.7^{ab}	86.3
2	20% RS[1] (raw)	29.6	18.5^{b}	68.9^{c}	23.4	18.1	67.3^{b}	26.9	12.0^{a}	84.0
3	20% RS (raw) + 0.2% arg.[2]	28.6	18.8^{b}	69.5^{c}	21.7	14.4	74.1^{c}	26.6	10.0^{c}	86.6
4	20% RS (autoclaved)[3]	30.7	24.1^{a}	63.2^{ab}	22.8	17.4	67.2^{b}	26.4	10.2^{bc}	84.7
5	20% RS (autoclaved)+ 0.3% arg.	30.8	23.3^{a}	62.5^{ab}	24.2	18.7	66.9^{b}	26.1	9.7^{c}	80.4
6	20% RS (autoclaved)+ 0.2% arg.	30.1	23.7^{a}	65.1^{b}	25.3	16.2	71.1^{bc}	26.7	10.6^{bc}	82.7
7	20% RS (autoclaved)+ 0.1% arg.	30.0	23.7^{a}	62.0^{ab}	24.0	17.4	66.6^{ab}	26.3	10.7^{bc}	85.9
	SEM	0.5	1.2	0.8	1.6	2.0	1.8	0.4	0.4	2.0

[1] All RS rations contained additional 0.1% DL-methionine.

[2] arg. = L-arginine.

[3] Heated in the autoclave for 10 minutes at 120C.

[4] Column values with same superscript or no superscript are not significantly different ($P<0.05$).

[5] Values are expressed on a dry matter basis.

Summary

The effects of including different levels of arginine in rations of chicks containing RS were evaluated in terms of growth rate, feed conversion, relative organ weights (thyroid, liver and heart) and composition of the carcass, liver and heart. The results obtained indicated the following:

1. Inclusion of 20% raw RS in the ration significantly depressed growth rates and led to increased feed requirement per unit of gain. When 20% autoclaved RS was included in the ration, growth rates and feed efficiency were significantly improved.
2. None of the relative weights of the organs studied was significantly affected by dietary treatment. There was, however, a tendency for organ sizes to be larger for chicks fed rations containing raw RS.
3. The percentage of protein in the carcass and in the heart were higher, and fat contents were lower, in chicks fed RS rations than those of chicks fed the control ration. Changes in the percentage of fat and protein in the liver were slight.
4. The addition of varying levels of arginine to the rations had no appreciable effects on any of the parameters studied.

Trial 6

Object

Since 20% RS was the maximum level used previously in any rations, a trial was conducted to study the effects, on the performance of chicks, of adding 20, 30 or 40% autoclaved RS to rations for broiler chicks.

Experimental

Male chicks were used in this trial and were managed as described in Trial 3. The control and 20% Span RS rations were similar to the ones used in Trial 5 (Table 11). To obtain the rations containing 30 and 40% autoclaved Span RS, each additional 10% Span RS added above 20% replaced 8% wheat and 2% SBM in the ration. All rations were made isonitrogenous but no attempt was made to make the rations isocaloric because this would have required the addition of high levels of stabilized tallow to the control ration. The rations containing 30 and 40% autoclaved RS had metabolizable energy values of 3264 and 3409 kcals/kg diet, respectively.

At the end of the experiment, thyroids, livers and hearts were removed from 8 chicks per experimental group and treated as described in Trials 4 and 5. Eight chicks per experimental group were also selected for carcass analysis as described in Appendix 1. Carcasses, livers and hearts from each treatment were pooled in four groups of 2 before analysis.

Results and Discussion

Inclusion of 20% autoclaved RS in the ration (Table 14) resulted in weight gain higher than that of chicks fed raw RS (Group 3 vs. 2) and similar to that obtained on the control ration (Group 3 vs. 1). As the level of autoclaved RS was increased beyond 20% in the ration, weight gain was significantly depressed as compared to that obtained on the control ration (Groups 4 and 5 vs. 1). When 0.2% arginine was added to the rations containing 20 or 30% autoclaved RS, rate of gain was not significantly different from that obtained on the control ration,

TABLE 14. - Effects of varying levels of autoclaved rapeseed on average weight gain, feed conversion and organ weights of chicks.

Group no.	Dietary treatment	Wt gain[4] g	Feed conversion g feed / g gain	Thyroid wt mg/100g body wt	Liver wt g/100g body wt	Heart wt g/100g body wt
1	Control ration	451^{a}	1.85	7.5^{a}	2.11^{a}	0.533^{abcd}
2	20% RS[1] (raw)	373^{c}	2.14	15.9^{c}	2.40^{ab}	0.477^{d}
3	20% RS (autoclaved)[2]	425^{ab}	1.90	9.4^{ab}	2.47^{ab}	0.494^{cd}
4	30% RS (autoclaved)	405^{b}	1.91	10.0^{ab}	3.19^{c}	0.543^{abcd}
5	40% RS (autoclaved)	401^{b}	1.91	11.0^{ab}	2.79^{bc}	0.590^{a}
6	20% RS (autoclaved) + arg.[3]	435^{a}	1.85	8.4^{ab}	2.37^{ab}	0.514^{bcd}
7	30% RS (autoclaved) + arg.	428^{ab}	1.92	12.0^{b}	2.58^{ab}	0.553^{abc}
8	40% RS (autoclaved) + arg.	403^{b}	1.94	10.4^{ab}	2.58^{ab}	0.599^{a}
9	Control ration + meth.	446^{a}	1.84	8.0^{ab}	2.09^{a}	0.572^{ab}
	SEM	8	0.06	1.1	0.17	0.021

[1] All rapeseed rations contained additional 0.1% methionine.

[2] Heated in the autoclave for 10 minutes at 120C.

[3] arg. = 0.2% L-arginine; meth. = 0.1% DL-methionine.

[4] Column values with same superscript or no superscript are not significantly different ($P < 0.05$).

though slightly lower (Groups 6 and 7 vs. 1). Rate of gain of chicks on the 40% autoclaved RS ration was not improved by supplementation of the ration with 0.2% arginine (Group 8). The addition of 0.1% methionine to the control ration did not improve the growth rate of chicks fed this ration (Group 9).

Any differences in feed conversion among the groups were not significant. There was however a tendency for chicks placed on the ration containing raw RS (Group 2) to have a higher feed requirement per unit gain than for chicks fed the other rations.

The use of 20% raw RS in the ration resulted in an approximate doubling in relative thyroid weight (Table 14) as compared to that obtained on the control ration (Group 2 vs. 1). When autoclaved RS was used, relative thyroid weight was significantly reduced. Addition of 0.2% arginine to the rations had no predictable effect on the relative thyroid weights.

The relative liver weights of chicks fed rations containing RS tended to be higher than those of chicks fed the control ration (Table 14). There was also a tendency for increasing levels of autoclaved RS in the ration to result in increased relative liver weights, in a non-linear fashion (Groups 4 and 5 vs. 3; Groups 7 and 8 vs. 6). Relative weights of the hearts of chicks fed RS in their rations were in most cases similar to those obtained on the control ration. There was, however, a tendency for relative heart weights to increase as the level of autoclaved RS in the ration was increased.

Results on carcass composition (Table 15) resembled those obtained in Trials 4 and 5 in that the rations containing RS produced leaner carcasses than those obtained on the control ration. Inclusion

TABLE 15. - Effects of varying levels of autoclaved rapeseed on carcass, heart and liver composition of chicks.

Group No.	Dietary treatment	Carcass Dry matter[4] %	 Fat[5] %	 Protein[5] %	Heart Dry matter %	 Fat[5] %	 Protein[5] %	Liver Dry matter %	 Fat[5] %	 Protein[5] %
1	Control ration	34.2^{a}	24.8^{a}	55.0^{a}	24.2^{a}	18.3^{ab}	69.8	26.7	10.8	79.9
2	20% RS[1] (raw)	30.7^{bc}	18.1^{bc}	66.6^{bc}	23.8^{ab}	14.0^{cde}	72.8	27.4	9.5	80.8
3	20% RS (autoclaved)[2]	30.8^{bc}	21.7^{ab}	64.9^{bc}	22.8^{bc}	15.7^{bcd}	70.8	26.6	10.1	79.6
4	30% RS (autoclaved)	29.8^{bc}	17.8^{bc}	66.6^{bc}	22.3^{cd}	17.2^{abc}	69.9	25.5	8.9	80.8
5	40% RS (autoclaved)	29.2^{c}	16.9^{c}	69.6^{c}	22.4^{cd}	13.5^{de}	69.9	26.4	9.1	80.1
6	20% RS (autoclaved) + arg.[3]	30.2^{bc}	19.6^{bc}	66.0^{bc}	21.2^{d}	11.6^{e}	73.1	25.8	9.4	79.9
7	30% RS (autoclaved) + arg.	30.1^{bc}	18.2^{bc}	67.9^{bc}	22.0^{cd}	13.9^{cde}	70.9	26.0	10.3	81.6
8	40% RS (autoclaved) + arg.	29.8^{bc}	18.9^{bc}	66.4^{ab}	22.2^{cd}	15.0^{bcde}	70.4	26.4	10.4	80.9
9	Control ration + meth.[3]	32.9^{ab}	25.4^{a}	61.1^{ab}	22.6^{bc}	20.4^{a}	68.3	26.6	11.1	79.7
	SEM	0.8	1.3	2.3	0.4	1.0	1.0	0.4	0.5	0.8

[1] All rapeseed rations contained additional 0.1% methionine.

[2] Heated in the autoclave for 10 minutes at 120C.

[3] arg. = 0.2% L-arginine; meth. = 0.1% DL-methionine.

[4] Column values with same superscript or no superscript are not significantly different ($P \angle 0.05$).

[5] Values are expressed on a dry matter basis.

of raw RS in the ration (Group 2) resulted in significantly lower percentages of carcass dry matter and fat and significantly higher percentages of carcass protein than those obtained for chicks fed the control ration (Group 1). When 20% autoclaved RS was used in the ration, the percentage carcass dry matter obtained was significantly lower than that of the control ration (Group 3 vs. 1) and not different from that of the ration containing 20% raw RS (Group 3 vs. 2). The percentage carcass fat obtained was slightly higher, and the carcass protein slightly lower, than those obtained on the ration containing raw RS (Group 3 vs. 2). The use of 30 and 40% autoclaved RS in the ration (Groups 4 and 5) significantly depressed percentage carcass fat and increased percentage carcass protein as compared to those obtained on the control rations (Groups 1 and 9). The addition of 0.2% arginine to the RS rations (Groups 6, 7 and 8) or 0.1% methionine to the control ration (Group 9) did not appreciably alter carcass composition.

The effects of treatment on the composition of the hearts and livers are summarized in Table 15. The percentage dry matter content of the hearts of chicks fed the control ration (Group 1) was significantly higher than that of the other groups except those receiving raw RS ration (Group 2). In general, the percentage of fat in hearts of chicks fed rations containing RS (Groups 2 to 8) was lower than that of chicks fed the control rations (Groups 1 and 9) but any differences amongst the groups in the protein content of the hearts were not significant. Composition of the livers of chicks was not significantly affected by the dietary treatments used.

Summary

The effects of varying the levels of autoclaved RS in the ration on performance of chicks were studied in this trial. The results obtained indicated the following:

1. The inclusion of raw RS in the ration significantly depressed growth rates and increased relative thyroid weights of chicks.
2. The inclusion of 20% autoclaved RS in place of 20% raw RS in the ration resulted in a significant improvement in growth rates and reduced relative thyroid weights.
3. As the level of autoclaved RS in the ration was increased beyond 20%, the growth rates of chicks were significantly depressed as compared to those obtained on the control rations.
4. Inclusion of 0.2% arginine in the rations containing 20 and 30% autoclaved RS tended to increase the growth rates of chicks.
5. There was a tendency for the relative weights of the livers and hearts to increase with higher level of autoclaved RS in the ration.
6. Rations containing RS produced leaner carcasses than those produced on the control ration. The inclusion of raw RS in the ration resulted in higher percentage carcass protein and lower percentage carcass fat than those obtained on the control ration. When 20% autoclaved RS was fed to the chicks in their ration, the carcass composition fell midway between that on the ration containing 20% raw RS and that of the control ration.
7. Inclusion of RS in the ration did not result in increased fat deposition in the hearts and livers of chicks.

C. Assessment of other factors affecting the nutritive value of rapeseed for broiler chicks

Status of the Problem

Previous trials had indicated that autoclaving RS improved its nutritive value and reduced its goitrogenicity for broiler chicks; however, chicks fed rations containing autoclaved RS tended to grow slightly slower than those fed the control ration. It was also noted that the leanest carcasses were obtained on rations containing raw RS while the fat content of the carcasses of chicks fed rations containing autoclaved RS tended to fall midway between those fed the control ration and those fed rations containing raw RS.

The above observations suggested that differences in nutrient utilization and the effect of inactivation of myrosinase by autoclaving might be responsible for the differences in growth rates, thyroid weights and carcass composition that were obtained. In order to establish whether these factors were the principal ones involved, trials were initiated to assess the effects of use of RS or RSM varieties of varying glucosinolate content, the use of RSO or stabilized tallow, the effect of autoclaving and protein level on the utilization of nutrients by, and performance of, chicks.

Trial 7

Object

To assess the use of 2 varieties of RS and RSM (Span and Bronowski) which varied in glucosinolate content and 2 types of fat (RSO and stabilized tallow) in rations for broilers.

Experimental

Four lots of 10 chicks (5 males and 5 females per lot) were selected at 7 days old as described previously (Trial 3) and placed at random on each of the experimental rations. During the experiment, the chicks were managed as described in Trial 3.

The composition of the basal rations used (Basals 12 to 15) is shown in Table 16. A level of 20% RS was used in the basal rations containing RS. RSM, when used, was included in the rations at the 12% level and RSO was added at a level of 8% which would be approximately equivalent to the amount of RSM and RSO contributed by 20% full-fat RS. The RSO used was from Span RS. The same M.E. value was assumed for both varieties of RS (4400 kcal/kg) and for the meals derived from each variety (1760 kcal/kg). When methionine and arginine were added to the rations, the levels of glutamic acid and corn starch were adjusted so that all rations were isocaloric and isonitrogenous.

At the end of the 3 weeks experimental period, 4 chicks (2 males plus 2 females) were selected from each lot, (16 chicks per experimental group) after an overnight fast, killed by cervical dislocation and the thyroids, liver and heart removed and treated as described in Trials 4 and 5. Similarly, another group of 4 chicks (2 males plus 2 females) were randomly selected per lot (16 chicks per experimental group) after an overnight fast and the carcasses were analysed as described in Appendix 1. At time of analysis, the 2 organ samples (liver or heart) or carcasses for each sex per lot were pooled and analysed compositely. Body composition was also determined on 12 chicks killed initially (Day 7 post-hatching) so that the nutrients retained and utilised over the 3 weeks experimental

TABLE 16. - Composition of basal rations - Trial 7.

	Basal ration number			
	12 Control ration %	13 20% RS %	14 RSM + RSO %	15 RSM + Stab. tallow %
Ground wheat (13.0% protein)	54.00	48.00	48.00	45.00
Soybean meal (48.5% protein)	31.75	24.75	24.75	25.50
Whole rapeseed	-	20.00	-	-
Rapeseed meal	-	-	12.00	12.00
Rapeseed oil	-	-	8.00	-
Stabilized tallow	7.50	0.50	0.50	10.75
Dehydrated alfalfa	1.00	1.00	1.00	1.00
Ground limestone (38.0% Ca)	1.75	1.75	1.75	1.75
Calcium phosphate (18.5% Ca; 20.5P)	1.50	1.50	1.50	1.50
Premix[1]	0.50	0.50	0.50	0.50
Iodized salt (150 ug I/kg)	0.25	0.25	0.25	0.25
Manganese oxide (62% Mn)	0.02	0.02	0.02	0.02
Zinc oxide (78.5% Zn)	0.01	0.01	0.01	0.01
Glutamic acid	1.35	1.35	1.35	1.35
Cornstarch	0.37	0.37	0.37	0.37
Composition				
Protein (%) calculated	23.5	23.5	23.5	23.5
Protein (%) analysed	24.1	24.1	23.9	24.0
Fat (%) analysed	9.4	10.3	10.4	12.5
Dry matter (%) analysed	90.0	89.7	89.7	89.9
Calcium (%) calculated	1.01	1.03	1.03	1.03
Total Phosphorus (%) calculated	0.74	0.76	0.76	0.76
M.E.kcal/kg diet, calculated	3120	3120	3120	3120

[1] See Table 2 for composition of premix.

period could be calculated.

Myrosinase activity in RS was determined by the method of Schimmer (1961) with slight modifications (Appendix II). Glucosinolate content of RS was determined by the method of Appelqvist and Josefsson (1967).

Results and Discussion

A summary of the effects of dietary treatment on average weight gain, feed conversion and organ-to-body weight ratios (relative organ weights) is presented in Table 17.

The inclusion of raw Span RS in the ration resulted in a significant depression in weight gain, higher feed requirement per unit gain and an approximate doubling of relative thyroid weights as compared to those obtained on the control ration (Group 2 vs. 1). When autoclaved Span RS was included in the ration, weight gain and feed conversion were significantly improved and relative thyroid weight was significantly reduced (Group 3 vs. 2). Similar results were noted with the rations containing Bronowski RS (Group 10 vs. 9) except that the enlargement of the thyroid was of less magnitude than in the case of raw Span RS (Group 9 vs. 2).

Improvement brought about by autoclaving raw Bronowski RS was less than that brought about by autoclaving raw Span RS (Group 10 vs. 9; and Group3 vs. 2). Use of raw Bronowski RS in the ration resulted in chick weight gain, and feed conversion superior to those on rations containing raw Span RS (Group 9 vs. 2). When either autoclaved Span or Bronowski RS was fed, performance of chicks were similar (Group 3 vs. 10) and equivalent to that attained on the

TABLE 17. - Effects of variety of rapeseed, or rapeseed meal and type of fat fed on average weight gain, feed conversion and organ weights of chicks.

Group No.	Dietary treatment	Wt gain[3] g	Feed conversion g feed / g gain	Thyroid wt mg/100g body wt	Liver wt g/100g body wt	Heart wt g/100g body wt
1	Control ration	418^{def}	1.82^{cd}	8.0^{ab}	2.06^{ab}	0.432
2	Raw Span RS	341^{h}	2.16^{g}	15.0^{e}	2.32^{de}	0.510
3	Autoclaved[1] Span RS	405^{fg}	1.91^{ef}	10.0^{cd}	2.21^{abcde}	0.448
4	Autoclaved Span + meth. + arg.[2]	408^{efg}	1.90^{ef}	9.2^{abcd}	2.27^{bcde}	0.454
5	Span RSM + Span RSO	416^{def}	1.78^{bcd}	9.1^{abcd}	2.19^{abcde}	0.466
6	Span RSM + Span RSO + meth. + arg.	424^{bcde}	1.72^{ab}	9.2^{abcd}	2.25^{bcde}	0.458
7	Span RSM + stab. tallow	419^{cdef}	1.81^{cd}	9.7^{bcd}	2.25^{bcde}	0.481
8	Span RSM + stab. tallow + meth. + arg.	434^{abc}	1.79^{bcd}	8.0^{ab}	2.19^{abcde}	0.439
9	Raw Bronowski RS	396^{g}	1.93^{f}	10.1^{d}	2.13^{abcd}	0.410
10	Autoclaved Bronowski RS	413^{def}	1.83^{de}	8.7^{abcd}	2.31^{cde}	0.443
11	Autoclaved Bronowski RS + meth. + arg.	415^{def}	1.84^{de}	8.7^{abcd}	2.16^{abcde}	0.445
12	Bronowski RSM + Span RSO	427^{bcd}	1.76^{abc}	9.0^{abcd}	2.09^{abc}	0.445
13	Bronowski RSM + Span RSO + meth. + arg.	439^{ab}	1.68^{a}	8.8^{abcd}	2.00^{a}	0.442
14	Bronowski RSM + stab. tallow	449^{a}	1.73^{ab}	7.8^{a}	2.01^{a}	0.401
15	Bronowski RSM + stab. tallow + meth. + arg.	447^{a}	1.73^{ab}	8.3^{abc}	2.14^{abcd}	0.426
	SEM	5	0.02	0.5	0.07	0.010

[1] Heated in the autoclave for 10 minutes at 120C.

[2] Meth. = 0.1% DL-Methionine, arg. = 0.2% L-arginine.

[3] Column values with same superscript or no superscript are not significantly different ($P<0.05$).

control ration (Group 1). Supplementation of the autoclaved RS rations with arginine and methionine had no significant effect on the performance of chicks (Groups 4 and 11 vs. Groups 3 and 10 respectively).

The inclusion of 12% Span RSM in the ration (Groups 5 to 8) gave the same weight gain and feed conversion as those obtained on the control ration (Group 1). The inclusion of 12% Bronowski RSM to the rations (Groups 12 to 15) in place of Span RSM resulted in more rapid growth and slightly better feed conversion. The growth rate and feed conversion efficiency of chicks fed Bronowski RSM plus stabilized tallow ration (Group 14) were significantly higher than those of chicks fed the control ration (Group 1) or the Span RSM plus stabilized tallow ration (Group 7). Supplementation of the ration containing Span RSM and stabilized tallow with methionine and arginine led to growth rates and feed conversion of chicks not significantly different from those obtained on the ration containing Bronowski RSM plus stabilized tallow (Group 8 vs. 14 and 15). Both types of RSM produced similar relative thyroid weights which were in turn not significantly different from those produced on the control ration.

The type of fat fed apparently had an effect on the performance of chicks only when Bronowski RSM was used. Inclusion of stabilized tallow in the ration resulted in significantly improved weight gain as compared to rations containing RSO in the ration (Group 14 vs. 12); however when the rations were supplemented with arginine and methionine, no significant difference was noted (Group 15 vs. 13).

The performance obtained when RSM and RSO were included separately in the ration (Groups 5 and 6; 12 and 13) was slightly superior to that of chicks fed rations containing autoclaved RS (Groups 3 and 4; 10 and 11). Such differences, though small, are perhaps sufficient to account for the slightly lower performance of chicks fed the autoclaved Span RS ration as compared to that of chicks fed the control ration in this and earlier trials (Trials 4 to 6). The differences in response between chicks fed RSO or stabilized tallow and Span or Bronowski RSM in their rations, were not as great as the differences in response between chicks fed raw Span or raw Bronowski RS in their rations. The results suggest that the greater goitrogenicity of raw Span RS may have been an important factor in reducing performance of chicks.

Since there were no significant differences because of sex or treatment interactions, the data on relative liver weights (Table 17) were combined. Inclusion of raw Span RS in the ration (Group 2) resulted in significantly heavier relative liver weights than those obtained on the control ration (Group 1). Autoclaving Span RS before inclusion in the ration resulted in slightly lower relative liver weights (Groups 3 and 4 vs. 2). The use of raw Bronowski RS in the ration did not increase relative liver weights above those obtained on the control ration (Group 9 vs. 1). Autoclaving Bronowski RS may have increased, rather than decreased, relative liver weights of chicks (Group 10 vs. 9). There was a tendency for relative liver weights obtained on the Bronowski RSM rations (Groups 12 to 15) to be slightly lower than those obtained on the rations containing Span RSM (Groups 5 to 8). Type of fat fed or inclusion of amino acids to the rations did not significantly affect the relative liver weights of chicks.

The relative weight of hearts of chicks was not affected by the treatments used. Relative heart weights of females were generally significantly lower than those of male chicks but there was no significant sex-treatment interaction.

The level of glucosinolates in the two varieties used indicated that Bronowski RS contained much lower levels of oxazolidinithione and isothiocyanates than Span RS (Table 18), probably accounting for the lower goitrogenicity of raw Bronowski RS. The reduced goitrogenicity of autoclaved Span RS is probably related to a less release of goitrin because of inactivation of the enzyme, myrosinase (Table 18). Autoclaving Bronowski RS also completely destroyed myrosinase activity.

No interaction between sex and treatment on carcass composition (Table 19) was observed. There was however a significant effect of sex on carcass composition. Female chicks had a significantly higher proportion of carcass dry matter and fat and a lower proportion of carcass protein than did male chicks. Chicks fed the control ration (Group 1) had carcasses with a significantly higher percentage dry matter and fat and a lower percentage protein than those fed rations containing raw RS in their rations (Groups 2 and 9). The rations containing autoclaved Span RS produced carcasses with higher percentage dry matter, higher percentage fat and lower percentage protein than those produced on raw Span RS rations (Group 3 vs. 2) but autoclaving had no appreciable effect with rations containing Bronowski (Group 10 vs. 9). The percentage of carcass fat was significantly lower and percentage of carcass protein was significantly higher on rations containing autoclaved RS than those obtained on the control ration

TABLE 18. - Myrosinase activity and glucosinolates in rapeseed.

Type of RS	Type	Myrosinase activity (% of untreated RS)	ITC[2] mg/g seed meal	OZT[3] mg/g seed meal
Span	raw	100	2.24	2.59
Span	autoclaved[1]	0	2.12	2.46
Bronowski	raw	100	0.54	0.67
Bronowski	autoclaved[1]	0	0.52	0.67

[1] Heated in the autoclave for 10 minutes at 120C.

[2] Refers to isothiocyanates (as 3-butenyl isothiocyanate).

[3] Refers to oxazolidinethione (goitrin).

TABLE 19. - Influence of variety of rapeseed or rapeseed meal and type of fat fed on the carcass composition of chicks.

Group No.	Dietary treatment	Carcass Dry matter[3] %	Carcass Fat[4] %	Carcass Protein[4] %
1	Control ration	34.6^{ab}	36.3^{a}	54.1^{ab}
2	Raw Span RS	30.7^{f}	24.1^{e}	64.0^{c}
3	Autoclaved[1] Span RS	33.0^{bcde}	28.8^{cd}	59.1^{cd}
4	Autoclaved Span RS + meth. + arg.[2]	32.8^{cde}	26.8^{de}	60.1^{d}
5	Span RSM + Span RSO	34.0^{abcd}	32.0^{b}	55.8^{abc}
6	Span RSM + Span RSO + meth. + arg.	33.2^{abcde}	31.1^{bc}	58.0^{bcd}
7	Span RSM + stab. tallow	34.7^{ab}	35.9^{a}	53.7^{a}
8	Span RSM + stab. tallow + meth. + arg.	34.3^{abc}	37.0^{a}	54.4^{ab}
9	Raw Bronowski RS	31.9^{ef}	26.6^{de}	60.3^{d}
10	Autoclaved Bronowski RS	32.3^{def}	29.3^{bcd}	59.6^{cd}
11	Autoclaved Bronowski RS + meth. + arg.	32.4^{de}	27.8^{d}	59.5^{cd}
12	Bronowski RSM + Span RSO	33.3^{abcde}	32.1^{b}	56.6^{abcd}
13	Bronowski RSM + Span RSO + meth. + arg.	33.6^{abcde}	32.1^{b}	56.5^{abcd}
14	Bronowski RSM + stab. tallow	34.7^{ab}	37.0^{a}	54.3^{ab}
15	Bronowski RSM + stab. tallow + meth. + arg.	34.8^{a}	37.4^{a}	55.2^{ab}
	SEM	0.5	1.0	1.2

[1] Heated in the autoclave for 10 minutes at 120C.

[2] Meth. = 0.1% DL-methionine; arg. = 0.2% L-arginine.

[3] Column values with the same superscript are not significantly different ($P<0.05$).

[4] Values are expressed on a dry matter basis.

(Groups 3 and 10 vs. 1).

The results also indicated that RSM rations produced percentages of carcass fat similar to the control ration only when stabilized tallow replaced RSO in the RSM rations. There were no obvious differences in the proportion of dry matter, fat and protein of carcasses of chicks fed Span or Bronowski RSM rations. The percentage carcass fat obtained on the rations containing RSM and RSO (Groups 5, 6, 12 and 13) was slightly higher, and the percentage carcass protein slightly lower, than those obtained on the rations containing autoclaved RS (Groups 3, 4, 10 and 11). The addition of arginine and methionine to the rations did not significantly alter carcass composition.

Data on nutrient retention (Table 20) indicated that the inclusion of raw RS in the ration resulted in retention of lower amounts of dry matter, fat, protein and energy in the carcass as compared to those retained in the carcasses of chicks fed the control ration (Groups 2 and 9 vs. 1). Similar amounts of dry matter, fat and energy were retained in the carcasses of chicks fed rations containing autoclaved Span or autoclaved Bronowski RS (Groups 3 and 10), amounts significantly lower than those retained on the control ration (Group 1). Protein retention was similar for raw Bronowski, autoclaved Span and Bronowski, and the control rations. Significantly higher amounts of dry matter, fat, protein and energy were retained on ration containing raw Bronowski RS than on that containing raw Span RS (Group 9 vs. 2).

The results (Table 20) suggest that the replacement of RSO by stabilized tallow in the RSM rations led to retention of signifi-

TABLE 20. - Effects of variety of rapeseed or rapeseed meal and type of fat fed on nutrient retention, energy and protein utilization of chicks.

Group No.	Dietary treatment	Nutrient retention[3] Dry matter[4] g	Fat g	Protein g	Energy kcal	Utilization[5] Protein[4]	Energy[6]
1	Control ration	151.3^{c}	58.5^{a}	76.4^{de}	979^{bc}	41.9^{cd}	41.3^{cd}
2	Raw Span RS	108.2^{f}	27.2^{e}	65.9^{f}	627^{h}	37.4^{e}	27.4^{g}
3	Autoclaved[1] Span RS	139.5^{de}	42.2^{cd}	77.8^{cde}	835^{f}	41.9^{cd}	34.7^{e}
4	Autoclaved Span RS + meth + arg.[2]	139.7^{de}	39.2^{d}	79.4^{abcde}	816^{fg}	42.8^{bcd}	33.8^{ef}
5	Span RSM + Span RSO	147.9^{cd}	49.9^{b}	77.1^{cde}	903^{e}	43.5^{abcd}	39.2^{d}
6	Span RSM + Span RSO + meth. + arg.	146.6^{cd}	48.2^{bc}	80.1^{abcd}	904^{e}	46.0^{a}	39.9^{cd}
7	Span RSM + stab. tallow	152.4^{bc}	58.4^{a}	75.9^{de}	976^{bcd}	41.7^{cd}	41.2^{cd}
8	Span RSM + stab. tallow + meth. + arg.	155.5^{abc}	61.2^{a}	79.1^{bcde}	1020^{ab}	42.5^{bcd}	42.1^{c}
9	Raw Bronowski RS	131.0^{e}	36.4^{d}	74.7^{e}	763^{g}	40.7^{d}	32.0^{f}
10	Autoclaved Bronowski RS	138.2^{de}	42.6^{cd}	77.9^{bcde}	839^{f}	42.9^{bcd}	35.5^{e}
11	Autoclaved Bronowski RS + meth. + arg.	139.5^{de}	40.5^{d}	78.4^{bcde}	823^{fg}	42.9^{bcd}	34.6^{e}
12	Bronowski RSM + Span RSO	148.1^{cd}	50.3^{b}	78.9^{bcde}	916de	43.9^{abc}	39.2^{d}
13	Bronowski RSM + Span RSO + meth. + arg.	153.9^{abc}	52.1^{b}	81.7^{abc}	950^{cde}	46.1^{a}	41.3^{bcd}
14	Bronowski RSM + stab. tallow	162.7^{a}	64.0^{a}	82.9^{ab}	1067^{a}	44.6^{abc}	44.2^{ab}
15	Bronowski RSM + stab. tallow + meth. + arg.	161.9^{ab}	64.4^{a}	84.1^{a}	1078^{a}	45.4^{ab}	44.7^{a}
	SEM	3.3	2.1	1.5	20	0.9	0.9

[1] Heated in autoclave for 10 minutes at 120C.

[2] Meth. = 0.1% DL-methionine; arg. = 0.2% L-arginine.

[3] Expressed as final nutrients - initial nutrients.

[4] Column values with same superscript are not significantly different ($P \leq 0.05$).

[5] Calculated as amount of protein or energy retained in the carcass divided by amount of protein or energy consumed x 100.

[6] Final energy - initial energy; energy = g protein x 5.66 + g fat x 9.35 Kcal.

cantly higher amounts of fat and energy while protein retained was not significantly affected (Groups 5 and 6 vs. 7 and 8; Groups 12 and 13 vs. 14 and 15). The amounts of these nutrients retained by chicks were higher on the Bronowski RSM plus stabilized tallow rations than on the control rations (Groups 14 and 15 vs. 1) but were similar to the control when a ration containing Span RSM plus stabilized tallow was fed (Groups 7 and 8 vs. 1).

The inclusion of raw Span RS in the ration (Table 20) resulted in significantly lower protein and energy utilization than those obtained on the control ration (Group 2 vs. 1) or on the ration containing autoclaved Span RS (Group 2 vs. 3) While protein utilization of chicks fed the ration containing autoclaved Span RS was similar to that noted on the control ration, energy utilization was significantly lower (Group 3 vs. 1). Chicks fed raw Bronowski RS ration (Group 9) utilized protein to the same extent as chicks fed the control ration (Group 1) or autoclaved Bronowski RS ration (Group 10). Energy utilization by chicks on the raw Bronowski RS ration (Group 9) was significantly lower than that of chicks fed the control ration (Group 1) or ration containing autoclaved Bronowski (Group 10). The extent of protein and energy utilization by chicks fed ration containing raw Bronowski RS was significantly higher than that of chicks fed raw Span RS ration (Group 9 vs. 2); while they were similar when the autoclaved RS rations are compared (Group 10 vs. 3).

The inclusion of RSM and RSO in place of autoclaved RS resulted in increased utilization of energy (Groups 5 and 12 vs. Groups 3 and 10) but protein utilization was not significantly affected. Substitution of stabilized tallow for RSO in rations containing Bronowski RSM led to significantly higher energy utilization than was obtained on the control ration (Groups 14 and 15 vs. 1) or on the ration containing Span RSM and stabilized tallow (Groups 14 and 15 vs. 7 and 8). In general, protein utilization was not appreciably affected by the type of fat or variety of RSM used in the rations.

Data on the effect of treatment on the composition of the heart and liver (Table 21) indicated that the percentage dry matter, fat and protein was not significantly affected as compared to that noted on the control ration. Variety of RS or RSM used or substitution of tallow for RSO in the rations apparently had little effect on the composition of the heart or liver.

Summary

Two varieties of RS and RSM and two types of fat were compared in rations for chicks. Results obtained showed that:

1. Autoclaving RS before inclusion in the rations significantly improved growth rates and feed conversion and reduced relative thyroid weights as compared to those obtained on the ration containing raw RS.
2. Bronowski RSM or RS rations produced slightly better weight gain and feed conversion than those obtained on rations containing Span RSM or RS.
3. Performance of chicks fed RSM or autoclaved RS rations was similar to, or better than, that of chicks fed the control ration.
4. The relative weights of hearts were not significantly affected by the dietary treatment used.
5. Rations containing RS produced leaner carcasses than those

TABLE 21. - Influence of variety of rapeseed or rapeseed meal and type of fat fed on the composition of hearts and livers of chicks.

Group No.	Dietary treatment	Heart Dry matter[3] %	 Fat[4] %	 Protein[4] %	Liver Dry matter %	 Fat[4] %	 Protein[4] %
1	Conrol ration	24.0	22.5^{abc}	66.5	27.3	15.3^{abcde}	75.5
2	Raw Span RS	22.6	20.0^{bc}	69.5	26.8	13.3^{bcde}	78.2
3	Autoclaved[1] Span RS	24.6	20.1^{bc}	69.2	26.6	13.7^{bcde}	78.1
4	Autoclaved Span RS + meth. + arg.	22.1	22.9^{abc}	67.6	26.2	12.2^{e}	77.6
5	Span RSM + Span RSO	22.5	23.8^{ab}	67.3	26.4	14.6^{abcde}	76.0
6	Span RSM + Span RSO + meth. + arg.	23.1	21.5^{abc}	69.5	26.3	13.0^{de}	77.3
7	Span RSM + stab. tallow	22.6	25.2^{a}	65.0	25.9	13.8^{bcde}	77.2
8	Span RSM + stab. tallow + meth. + arg.	21.9	23.7^{ab}	67.9	26.4	13.2^{cde}	78.0
9	Raw Bronowski RS	23.0	19.4^{c}	70.3	27.5	13.6^{bcde}	77.6
10	Autoclaved Bronowski RS	22.9	19.2^{c}	69.8	26.5	14.5^{abcde}	76.8
11	Autoclaved Bronowski RS + meth. + arg.	23.1	18.8^{c}	69.9	27.4	14.3^{abcde}	76.2
12	Bronowski RSM + Span RSO	23.5	19.3^{c}	69.0	26.8	17.6^{a}	75.0
13	Bronowski RSM + Span RSO + meth. + arg.	23.0	22.3^{abc}	67.1	27.5	16.7^{ab}	76.3
14	Bronowski RSM + stab. tallow	22.6	22.6^{abc}	68.1	27.4	16.6^{abc}	76.2
15	Bronowski RSM + stab. tallow + meth. + arg.	24.3	21.7^{abc}	68.5	26.9	16.2^{abcd}	75.6
	SEM	0.9	1.3	1.1	0.7	1.0	1.2

[1] Heated in the autoclave for 10 minutes at 120C.

[2] Meth. = 0.1% DL-methionine; arg. = 0.2% L-arginine.

[3] Column values with same superscript or no superscript are not significantly different ($P < 0.05$).

[4] Values are expressed on a dry matter basis.

produced by the control ration.

6. Nutrients retained in the carcasses were lowest on the raw RS rations. Autoclaving RS increased the amounts of nutrients retained.
7. Energy utilization of chicks fed rations containing autoclaved RS was higher than that of those fed ration with raw RS. Energy utilization was significantly higher on the RSM and RSO rations than on the rations containing autoclaved RS.
8. Energy utilization of chicks fed RSM and RSO rations was similar to that of chicks fed the control ration. Chicks fed Bronowski RSM and stabilized tallow utilized energy more efficiently than those fed the control ration or the ration containing Span RSM and stabilized tallow.
9. The composition of hearts and livers, was not adversely affected by any of the dietary treatments employed.

Trial 8

Object

The previous trials (Trials 3 to 7) indicated that, though autoclaving RS before inclusion in rations for chicks improved the nutritive value of the ration, performance of chicks obtained on the rations containing autoclaved RS was still slightly below that of chicks fed the control ration. Moreover Trial 7 had indicated, via carcass analysis, that nutrient utilization (especially energy) was higher on the control ration than on rations containing autoclaved RS. Since such differences in nutrient utilization might account, in part at least, for the slight superiority of the control ration over rations containing full-fat RS, it seemed desirable to obtain more information on nutrient utilization.

The objective of Trial 8 was 4-fold:

1. To evaluate nutrient utilization via balance studies.
2. To compare RS and SBM in terms of their supplementary protein value.
3. To compare RS and stabilized tallow in terms of fat contributed by each to the ration.
4. To assess the influence of dietary protein level on the nutritive value of RS.

Experimental

Eight experimental rations were employed in this trial. Composition of the basal rations (Basals 16 to 19) used is shown on Table 22. The high protein basal rations (Basals 16 and 17) were similar to those used in previous trials (Trials 5 to 7). The low protein basal rations (Basals 18 and 19) were formulated to contain 15% protein. Since 20% Span RS contributed 4.2% protein to the rations, SBM was added at a level of 8.75% to also contribute 4.2% protein. Likewise, since 20% RS contributed 8% fat to the rations, stabilized tallow was added to the 15% protein ration in an amount to provide the same level of fat. The rations were kept isocaloric by varying the levels of corn starch and alpha floc (cellulose) in the rations.

The chicks (equal number of males and females) were raised as in Trial 7. Each ration was fed to 4 lots of 10 chicks (5 males and 5 females per lot). Excreta were quantitatively collected at 24 hour intervals at 26, 27 and 28 days of age. The excreta was blown

TABLE 22. - Composition of basal rations - Trial 8.

	Basal rations number			
	16 Control ration %	17 20% RS %	18 Control ration %	19 20% RS %
Ground wheat (13.0% protein)	54.00	48.00	70.00	70.00
Soybean meal (48.5% protein)	31.75	24.75	8.75	-
Whole rapeseed (21.0% protein)	-	20.00	-	20.00
Stabilized tallow	7.50	0.50	8.50	0.50
Dehydrated alfalfa	1.00	1.00	1.00	1.00
Ground limestone (38.0% Ca)	1.75	1.75	1.75	1.75
Calcium phosphate (18.5% Ca; 20.5 P)	1.50	1.50	1.50	1.50
Premix[1]	0.50	0.50	0.50	0.50
Iodized salt (150 ug I/kg)	0.25	0.25	0.25	0.25
Manganese oxide (62% Mn)	0.02	0.02	0.02	0.02
Zinc oxide (78.5% Zn)	0.01	0.01	0.01	0.01
Glutamic acid	1.35	1.35	1.35	1.35
Cornstarch	0.37	0.37	1.62	-
Alpha floc	-	-	4.75	3.12
Composition				
Protein (%) calculated	23.5	23.5	15.0	15.0
Protein (%) analysed	23.9	24.0	15.1	15.1
Fat (%) analysed	9.4	10.5	11.0	11.2
Dry matter (%) analysed	91.4	92.0	92.6	92.0
Calcium (%) calculated	1.01	1.03	1.01	1.03
Total Phosphorus (%) calculated	0.74	0.76	0.74	0.76
M.E.kcal/kg diet, calculated	3120	3120	3123	3123

[1] See Table 2 for composition of premix.

free of down and scales, well mixed and dried in an oven at 60C for 72 hours on the day of collection. At the end of the drying period the 3 excreta samples from each replicate were pooled, finely ground and stored in plastic bags at -30C. A record of feed consumption was kept. At time of excreta collection, any feed wasted was collected, weighed and substracted from the amount of feed consumed.

The dried, ground excreta samples and feed were analysed for nitrogen, dry matter and fat (A.O.A.C., 1965). Gross energy was estimated using a Parr Oxygen Bomb Calorimeter. From these values, the amounts of nutrients retained were calculated. Classical metabolizable energy (M.E.) values were corrected for nitrogen ($M.E_N$) according to the method of Hill and Anderson (1958).

Results and Discussion

The treatment used and their effect on average weight gain, feed conversion and caloric consumption are summarized in Table 23.

As in earlier trials (Trials 4 to 7), the inclusion of 20% raw RS in the ration resulted in a significant decline in the rate of growth and increased feed requirement per unit gain as compared to the ration containing 20% autoclaved RS (Group 2 vs. 3; 6 vs. 7), or the control ration (Group 2 vs. 1; 6 vs. 5). Performance of chicks fed the rations containing autoclaved RS was slightly below that of chicks fed the control ration (Group 3 vs. 1; Group 7 vs. 5). The addition of methionine and arginine to the rations containing autoclaved RS significantly improved growth rates of chicks (Groups 3 and 7 vs. 4 and 8). In general, performance of chicks on the low protein rations was significantly less than that on the high protein ration

TABLE 23. - Effects of dietary protein level, supplementary protein and fat source on the weight gain, feed conversion and caloric intake of chicks.

Group No.	Dietary treatment	Wt gain[3] g	Feed conversion $\frac{\text{g feed}}{\text{g gain}}$	Caloric intake[4] kcal/bird
	A. High protein ration (24%)			
1	Control ration	433^{a}	1.74^{a}	2423^{a}
2	20% raw RS	347^{d}	2.04^{b}	2177^{c}
3	20% autoclaved[1] RS	405^{c}	1.83^{a}	2292^{abc}
4	20% autoclaved RS + meth. + arg.[2]	420^{b}	1.84^{a}	2395^{ab}
	B. Low protein ration (15%)			
5	Control ration	240^{e}	2.86^{c}	2373^{ab}
6	20% raw RS	165^{h}	3.27^{d}	1768^{e}
7	20% autoclaved RS	225^{g}	2.81^{c}	2022^{d}
8	20% autoclaved RS + meth. + arg.	234^{f}	2.87^{c}	2259^{bc}
	SEM	1	0.07	47

[1] Heated in the autoclave for 10 minutes at 120C.

[2] Meth. = 0.1% DL-methionine; arg = 0.2% L-arginine.

[3] Column values with same superscript are not significantly different ($P<0.05$).

[4] Calculated by multiplying feed consumed by Classical M.E. (Table 24).

(Groups 1 to 4 vs. Groups 5 to 8). The differences in ration protein levels did not alter the relative ranking of the dietary treatments.

Amounts of calories consumed are also presented in Table 23. The lowest level of caloric intake was noted on rations containing raw RS (Groups 2 and 6) and the highest level on the control ration (Groups 1 and 5) with an intermediate intake on the rations containing autoclaved RS (Groups 3, 4, 7 and 8).

Data on retention of nutrients are presented in Table 24. In general, a higher proportion of the dry matter, protein, fat and energy consumed was retained by chicks fed the 15% protein rations than by those fed the 23.5% protein rations.

Protein retention of chicks was not affected by inclusion of RS (raw or autoclaved) in the rations. There was a slight improvement in protein retention due to the addition of arginine and methionine to the rations containing autoclaved RS (Groups 3 vs. 4; 7 vs. 8).

The percentages of dry matter, fat and energy retained by chicks fed the control rations (Groups 1 and 5) were significantly higher than those of chicks fed RS in their rations (Groups 2 to 4; 6 to 8). Including autoclaved RS in the ration had no significant effect on the percentages of dry matter and energy retained as compared to the rations containing raw RS (Groups 3 and 7 vs. Groups 2 and 6). While the use of autoclaved RS in place of raw RS in the ration significantly improved fat retention on the high protein ration (Group 3 vs. 2), a similar effect was not observed on the lower protein ration (Group 7 vs. 6).

The higher energy retention on the control rations resulted

TABLE 24. - Influence of dietary protein level, supplementary protein and fat sources on retention of dry matter, protein, fat and energy; and dietary metabolizable energy for chicks.

Group No.	Dietary treatment	RETENTION Dry matter[3] %	RETENTION Protein %	RETENTION Fat %	RETENTION Energy %	METABOLIZABLE ENERGY (M.E.) kcal/g diet Classical M.E.	METABOLIZABLE ENERGY (M.E.) kcal/g diet M.E._{N}^{4}
	A. High protein rations (24%)						
1	Control ration	66.4^{b}	47.3^{bc}	88.6^{b}	72.3^{b}	3.22^{b}	3.07^{c}
2	20% raw RS	62.1^{c}	45.6^{c}	73.9^{f}	67.6^{c}	3.08^{c}	2.93^{d}
3	20% autoclaved[1] RS	61.4^{c}	45.2^{c}	79.3^{d}	67.1^{c}	3.08^{c}	2.94^{d}
4	20% autoclaved RS + meth. + arg.[2]	61.0^{c}	47.2^{bc}	76.4^{e}	67.2^{c}	3.09^{c}	2.94^{d}
	B. Low protein rations (15%)						
5	Control ration	70.5^{a}	50.6^{a}	91.8^{a}	75.5^{a}	3.46^{a}	3.36^{a}
6	20% raw RS	68.3^{b}	51.3^{a}	83.7^{c}	72.0^{b}	3.28^{b}	3.17^{b}
7	20% autoclaved RS	66.5^{b}	49.4^{ab}	82.9^{c}	71.4^{b}	3.20^{b}	3.10^{bc}
8	20% autoclaved RS + meth. + arg.	68.0^{b}	51.9^{a}	83.3^{c}	73.2^{b}	3.42^{a}	3.32^{a}
	SEM	0.7	0.9	0.5	0.8	0.03	0.03

[1] Heated in the autoclave for 10 minutes at 120C.

[2] Meth. = 0.1% L-methionine; arg. = 0.2% L-arginine.

[3] Column values with same superscript are not significantly different ($P<0.05$).

[4] Calculated as classical M.E. - [8.22 (nitrogen/g diet - nitrogen/g excreta)]

in significantly higher M.E. values for these rations (Groups 1 and 5) as compared to the rations containing RS (Groups 2 to 4; 6 and 7). Addition of methionine and arginine to the low protein ration containing autoclaved RS significantly improved the M.E. value of the ration (Group 7 vs. 8). The application of the nitrogen correction factor did not affect the relationships between the M.E. values, an observation similar to that of Baldini (1961).

The M.E. values of the rations containing RS (Groups 2 and 3; 6 and 7) were similar. The higher M.E. values of the control ration may be responsible, at least in part, for the slight but consistently higher growth rates and better feed efficiency for chicks fed this ration as compared to chicks fed rations containing autoclaved RS.

Summary

A trial was conducted to study the nutritive value of RS in terms of nutrient utilization, supplementary protein value, supplementary fat value and influence of dietary protein levels on chick performance. The following results were obtained:

1. Inclusion of raw Span RS in the rations for chicks resulted in a decrease in growth rates, increased feed requirement per unit gain and decreased caloric intake on both the 23.5% and 15% protein rations.
2. When RS was autoclaved before inclusion in the ration, growth rates and feed conversion were significantly improved over those of chicks fed the rations containing raw RS. Addition of methionine plus arginine to the ration containing autoclaved RS significantly improved the growth rates of chicks.
3. Chicks fed the control rations performed slightly better than

chicks on the rations containing autoclaved Span RS. Dietary protein levels had no effect on the relative rankings of the various treatments.

4. Chicks fed rations containing RS retained the same percentage of protein as chicks fed the control ration. Fat and energy retained on the control ration were significantly higher than those on the RS rations. Autoclaving the RS did not affect the percentage of fat or energy retained to any appreciable degree.
5. The M.E. of the control rations were significantly higher than those of the rations containing RS. Rations containing raw or autoclaved RS had the same M.E. value.

SECTION 2

Studies on the use of rapeseed meal and of unextracted rapeseed on the productive performance of laying chickens.

Status of the Problem

Rapeseed meal has recently been implicated as a possible causative factor in the occurrence of "fatty liver syndrome" and hepatic haemorrhage in laying birds. For this reason, data on the effect of RSM and full-fat RS on gross composition and condition of the liver and heart, as well as information on mortality and occurrence of "fatty liver syndrome" would be desirable.

Consequently, studies were undertaken to obtain information on the utilization of RSM and full-fat RS by laying chickens. The studies are reported under the following headings:

A. The effects of varying levels of RSM on the performance of laying chickens--Trials 1 and 2.

B. The utilization of full-fat RS by laying chickens--Trial 3.

Experimental (General)

Single Comb White Leghorn pullets were raised on commercial-type growing rations until they were 22 weeks old. At 22 weeks of age, they were leg banded and placed at random in laying cages (2 birds per 30 x 40 cm cage), and fed a commercial-type laying ration until 24 weeks of age when they were placed on the experimental rations. Each experimental ration was fed ad libitum to duplicate lots of 48 pullets per lot. During the experimental period of 336 days, records were kept on mortality, egg production (daily group average), egg weight (average weight of eggs laid by each group on one day of each week), Haugh unit values and specific gravity (average of determination on eggs laid by each group on one day at four week intervals), body weight at start and end of experiment and feed consumption recorded at 4 week intervals. The birds were given 14 hours of artificial light each day during the laying period.

Two trials with RSM and one trial with full-fat RS were conducted. At the end of Trials 2 and 3, 12 birds per lot (24 birds per experimental group) were killed by cervical dislocation and the thyroids, liver and heart removed and weighed. At time of removal, the hearts and livers were examined for any external abnormalities. The hearts and livers were then analysed for dry matter, fat and protein by the method described in Appendix I.

During the trials, any birds that died were sent to the veterinary laboratory for autopsy to ascertain the cause of death.

Data collected in the trials were subjected to analysis of variance. The analyses of variance of the data for mortality and "fatty liver syndrome" were based on the arc sin transformed data although the data presented on the table are the original data. Significance of differences were assessed by applying Duncan's Multiple Range Test (Steele and Torrie, 1960) at the 0.05 level of probability. Details of the analysis of variance are presented in Appendix VII.

A. The effects of varying levels of rapeseed meal on the performance of laying chickens - Trials 1 and 2.

Object

Since high levels of RSM in laying rations may cause increased mortality, trials were conducted to evaluate the use of varying levels of Span RSM in rations for laying chickens.

Experimental

The composition of the experimental rations (Rations 1 to 4) is shown in Table 25. Each of the rations was fed to duplicate lots of 48 pullets kept in laying batteries (see Experimental-General page 82).

Results and Discussion

Trial 1

The inclusion of 5 or 7.5% RSM in the ration did not significantly increase mortality above that obtained on the control ration (Table 26). The inclusion of 10% RSM in the ration, however, resulted in significantly increased mortality as compared to that noted on the control ration. On autopsy, mortality attributed to "fatty liver syndrome" increased progressively as the level of RSM in the ration was increased.

Egg production (hen-housed and hen-day) was not significantly affected by inclusion of 5 or 7.5% RSM in the rations (Table 26); however when the level of RSM was increased to 10%, a significant depression in egg production was noted. Egg Haugh unit values, specific gravity and egg weight were not appreciably affected by dietary treatments employed.

The best feed efficiency (feed per dozen eggs) was obtained on the rations containing 5 and 7.5% RSM but even 10% RSM did not significantly depress feed efficiency as compared to that obtained on

TABLE 25. - Composition of laying rations - Trials 1 and 2.

Ingredients	Ration number			
	1 Control ration %	2 5% RSM %	3 7.5% RSM %	4 10% RSM %
Ground wheat (14% protein)	79.5	75.80	73.95	72.10
Soybean meal (48.5% protein)	7.5	4.90	3.60	2.30
Span rapeseed meal (35% protein)	-	5.00	7.50	10.00
Stabilized tallow	1.0	2.30	2.95	3.60
Dehydrated alfalfa	2.00	2.00	2.00	2.00
Wheat shorts	0.21	0.21	0.21	0.21
Ground limestone (38.0% Ca)	7.00	7.00	7.00	7.00
Calcium phosphate (18.5% Ca; 20.5 P)	1.50	1.50	1.50	1.50
Iodized salt (150 ug I/kg)	0.25	0.25	0.25	0.25
Manganese oxide (62% Mn)	0.025	0.025	0.025	0.025
Zinc oxide (78.5% Zn)	0.01	0.01	0.01	0.01
Copper sulfate	0.005	0.005	0.005	0.005
Premix[1]	1.00	1.00	1.00	1.00
Calculated analyses:				
M.E.kcal /kg diet	2754	2754	2754	2754
Protein (%)	15.2	15.2	15.2	15.2
Calcium (%)	3.02	3.04	3.05	3.06
Total Phosphorus (%) calculated	0.69	0.69	0.70	0.70

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[1] Supplied per kg ration: Vitamin A, 5000 I.U.; Vitamin D_3, 825 ICU; Vitamin E, 11 I.U.; Menadione sodium bisulfate, 1.0 mg; riboflavin, 3.3 mg; calcium pantothenate, 10.0 mg; niacin, 15.0 mg; Vitamin B_{12}, 0.0066 mg; pennicillin, 4.4 mg; folic acid, 1.0 mg; choline chloride, 0.5g; DL-methionine, 0.5 g.

TABLE 26. - Performance of laying chickens fed various levels of rapeseed meal - Trial 1.

	Control ration %	5% RSM %	7.5% RSM %	10% RSM %	SEM
Total mortality, %[1]	13.5^a	14.6^a	16.6^a	33.3^b	3.4
Mortality, (fatty liver syndrome) %	3.1	3.1	8.3	13.5	1.0
Production, hen-housed, %	68.2^a	68.2^a	65.9^a	55.4^b	2.3
Production, hen-day,%	73.8^a	72.7^a	72.2^a	65.9^b	1.1
Egg Haugh unit values	75.2	74.1	74.4	73.5	1.1
Egg specific gravity	1.08	1.08	1.08	1.08	0.0
Egg wt, g	58.2	57.8	57.6	57.9	0.4
Feed per dozen eggs, kg	2.04	1.97	1.96	2.16	0.03
Initial body wt, kg	1.74	1.75	1.73	1.70	0.02
Final body wt, kg	2.05	2.04	2.01	2.04	0.01

[1] Row values with same superscript or no superscript are not significantly different ($P<0.05$).

the control ration. Dietary treatment apparently had no effect on the body weight of the hens.

Trial 2

The results of Trial 2 (Table 27) were similar to those obtained in Trial 1. Level of mortality was highest on the highest level of RSM in the ration, although the differences in mortality were not significant. On autopsy, it was found that none of the mortality noted was caused by "fatty liver syndrome" when the ration contained either 0 or 5% RSM; however, when 7.5 and 10% RSM were used, mortality levels from "fatty liver syndrome" were 3.1 and 9.4% respectively. Thus in both trials, the overall level of mortality and the mortality attributable to "fatty liver syndrome" was low when either 0 or 5% RSM was included in the ration but increased when the level of RSM was increased to 7.5 and 10%.

As in Trial 1, only the highest level of RSM (10%) appreciably depressed egg production. Egg weight, Haugh unit values and egg specific gravity were not significantly affected by the dietary treatment used. The best feed efficiency was obtained on the ration containing 7.5% RSM, while those with 5 and 10% RSM had feed efficiency similar to that on the control ration.

The relative weights of hearts and livers were not significantly affected by dietary treatment used (Table 27) but relative thyroid weights were significantly increased by inclusion of RSM in the ration. On examination, hearts from all groups were grossly normal. The livers from the control group were grossly normal but some livers from groups receiving RSM showed evidence of "fatty liver" (Figure 2). The

TABLE 27. - Performance of laying chickens fed various levels of rapeseed meal - Trial 2.

	Control ration	5% RSM	7.5% RSM	10% RSM	SEM
Mortality, %	8.3	10.4	14.6	16.6	2.6
Mortality, (fatty liver syndrome), %	0.0	0.0	3.1	9.4	2.2
Production, hen-housed, %[1]	69.8^{a}	65.1^{ab}	65.4^{ab}	60.5^{b}	1.4
Production, hen-day, %	72.9^{a}	69.2^{b}	70.0^{ab}	66.0^{c}	0.8
Egg Haugh unit values	78.8	77.6	78.2	77.4	0.6
Egg specific gravity	1.08	1.08	1.08	1.08	0.0
Egg wt, g	55.5	55.2	55.0	55.4	0.3
Feed per dozen eggs, kg	1.85^{ab}	1.90^{a}	1.80^{b}	1.94^{a}	0.02
Initial body wt, kg	1.54	1.57	1.54	1.55	0.01
Final body wt, kg	1.83	1.86	1.82	1.77	0.03
Liver wt, g/100 g body wt	3.00	2.98	3.08	2.99	0.15
Heart wt, g/100 g body wt	0.32	0.30	0.30	0.31	0.02
Thyroid wt, mg/100 g body wt	12.84^{a}	32.04^{b}	31.90^{b}	38.28^{b}	1.88

[1] Row values with the same superscript or no superscript are not significantly different ($P < 0.05$).

Figure 2. "Fatty liver" (left) and normal livers (right) from laying chickens. The light portions appearing on the livers are merely light reflections.

affected livers often showed signs of haemorrhages which occurred generally or was confined to one of the lobes. The affected livers were usually pale, friable and brittle. The percentages of "fatty livers" (24 livers examined per experimental group) of the hens receiving 0, 5, 7.5 and 10% RSM were 0, 4.2, 4.2 and 8.4% respectively.

The description of the condition of the livers of the birds that died from "fatty liver syndrome" was similar to the one described above for "fatty liver" and shown in Figure 2. In addition, birds that died from "fatty liver syndrome" were essentially in fat condition at autopsy and in full-lay with an egg in the oviduct at the time of autopsy.

The absolute weights of livers and hearts and their composition of dry matter, fat and protein were not significantly affected by dietary treatment used (Table 28).

Summary

Single Comb White Leghorn pullets were fed rations containing 4 levels (0, 5, 7.5 and 10%) of RSM in trials that lasted for 336 days. It was observed that:

1. Level of mortality was low when either 0 or 5% RSM was included in the ration but increased when the level of RSM was increased in the ration. Inclusion of 10% RSM resulted in a significant increase in mortality in one trial.
2. Mortality attributed to "fatty liver syndrome" increased progressively as the level of RSM in the ration increased.
3. The inclusion of 5 or 7.5% RSM in the rations of layers did not appreciably affect egg production. The inclusion of 10% RSM in

TABLE 28. - Effects of level of rapeseed meal on the composition of livers and hearts of laying chickens.

	Control	5% RSM	7.5% RSM	10% RSM	SEM
LIVER[1]					
Wet wt, g	56.58	61.49	60.40	58.33	4.28
Dry matter, %	30.14	30.50	31.80	31.00	1.78
Protein, %	52.60	53.18	51.80	51.42	2.61
Fat, %	33.35	32.58	35.56	37.40	2.36
HEART[1]					
Wet wt, g	5.92	6.12	5.68	5.90	0.15
Dry matter, %	22.07	22.46	22.49	22.37	0.26
Protein, %	73.76	73.70	73.55	72.94	1.63
Fat, %	16.64	16.20	16.51	16.03	1.45

[1] All row values without superscript are not significantly different ($P < 0.05$).

the ration decreased egg production.

4. Egg Haugh unit values, egg specific gravity, egg weights, feed conversion and body weights of birds, were not affected by the dietary treatments used.
5. No adverse effects on the sizes and composition of the livers and hearts were observed. The thyroids were enlarged in the RSM groups.

B. The utilization of full-fat rapeseed by laying chickens - Trial 3.

Object

To evaluate the nutritive value of full-fat RS in rations for SCWL pullets.

Experimental

Span full-fat RS was steam-treated at 90C for 30 minutes after allowing an initial heating period to attain the required temperature in the steam chest. After steam treatment, the RS was air dried at room temperature. It was then mixed with an equal quantity of ground wheat and ground.

The composition of the experimental rations (Rations 5 to 8) is shown in Table 29. The rations were formulated to contain 0, 5, 10 and 15% steam-treated Span RS and were isocaloric and isonitrogenous. Each of the rations was fed to duplicate lots of 48 pullets kept in laying batteries (see Experimental-General page 82).

Results and Discussion

Although differences in level of mortality of birds on the various treatments did not reach statistical significance, the highest

TABLE 29. - Composition of the laying rations - Trial 3.

Ingredients	Control ration %	5% RS %	10% RS %	15% RS %
Ground wheat (13.5% protein)	70.6	69.2	67.8	66.4
Soybean meal (48.5% protein)	12.0	10.2	8.4	6.6
Span rapeseed (21% protein)	-	5.0	10.0	15.0
Stabilized tallow	5.4	3.6	1.8	-
Dehydrated alfalfa	2.0	2.0	2.0	2.0
Wheat shorts	0.16	0.16	0.16	0.16
Ground limestone (38.0% Ca)	7.0	7.0	7.0	7.0
Calcium phosphate (18.5% Ca; 20.5 P)	1.5	1.5	1.5	1.5
Iodized salt (150 ug I/kg)	0.25	0.25	0.25	0.25
Manganese oxide (62% Mn)	0.025	0.025	0.025	0.025
Zinc oxide (78.5% Zn)	0.01	0.01	0.01	0.01
Copper sulfate	0.005	0.005	0.005	0.005
Premix[1]	1.0	1.0	1.0	1.0
Methionine	0.05	0.05	0.05	0.05
Calculated analyses:				
Protein (%)	16.0	16.0	16.0	16.0
M.E., kcals/kg diet	2908	2908	2908	2908
Calcium (%)	3.03	3.04	3.05	3.06
Total Phosphorus (%) calculated	0.68	0.68	0.69	0.70

[1] See Table 25 for composition of premix.

level of mortality observed was on the ration containing 15% RS (Table 30). None of the mortality on the control ration or the ration containing 5% RS was caused by "fatty liver syndrome" but when 10 or 15% RS was used in the ration, some of the mortality observed was due to "fatty liver syndrome" (Table 30). The condition was similar to that described in Trial 2.

Egg production (hen-housed and hen-day) was not significantly affected by dietary treatment (Table 30). It was, however, observed that egg production decreased slightly with increase in the level of RS in the ration. None of the parameters of egg quality measured (Haugh unit value, egg specific gravity and egg weight) was significantly affected by dietary treatment nor was the feed required to produce a dozen eggs.

The relative weights of the livers and hearts were not significantly affected by dietary treatment but there was a significant progressive increase in the relative thyroid weights as the level of RS in the ration was increased (Table 30). On examination, hearts from all groups were grossly normal. Some of the livers from the groups fed RS in their rations showed evidence of "fatty livers" (Figure 2). The affected livers showed gross abnormalities similar to those described in Trial 2. The incidence of "fatty livers" (24 livers examined per experimental group) of the hens receiving 0, 5, 10 and 15% was 0, 4.2, 8.3 and 8.3% respectively.

The absolute weights of the hearts and livers and their composition of dry matter, fat and protein were not significantly affected by dietary treatment (Table 31).

TABLE 30. - Performance of laying chickens fed various levels of full-fat rapeseed - Trial 3.

	Control ration	5% RS	10% RS	15% RS	SEM
Mortality, %	7.2	11.4	10.4	16.6	4.8
Mortality, (fatty liver syndrome), %	0.0^{a}	0.0^{a}	3.1^{b}	4.2^{b}	0.3
Production, hen-housed, %	71.5	68.4	65.8	63.1	2.6
Production, hen-day, %	74.2	73.0	70.8	69.8	1.1
Egg Haugh units	77.2	78.4	78.0	76.9	0.5
Egg specific gravity	1.08	1.08	1.08	1.08	0.00
Egg wt, g	56.4	56.4	56.4	56.2	0.1
Feed per dozen eggs, kg	1.70	1.70	1.76	1.84	0.03
Initial body wt, kg	1.56	1.55	1.56	1.58	0.0
Final body wt, kg	1.92	1.87	1.91	1.87	0.03
Liver wt, g/100 g body wt	2.85	2.84	2.85	2.88	0.12
Heart wt, g/100 g body wt	0.29	0.28	0.31	0.31	0.01
Thyroid wt[1], mg/100 g body wt.	14.57^{a}	28.86^{b}	40.26^{c}	52.63^{d}	2.07

[1] Row values with the same superscript or no superscript are not significantly different ($P < 0.05$).

TABLE 31. - The effects of level of full-fat rapeseed on the composition of livers and hearts of laying chickens.

	Control	5% RS	10% RS	15% RS	SEM
LIVER[1]					
Wet wt, g.	59.10	58.92	57.30	57.32	2.7
Dry matter,%	29.70	30.24	28.26	29.71	1.42
Protein, %	55.34	53.78	59.13	56.79	4.23
Fat, %	39.74	38.60	33.76	36.62	6.28
HEART[1]					
Wet wt, g.	5.96	5.65	6.10	6.04	0.31
Dry matter, %	21.92	21.52	22.68	22.06	0.46
Protein, %	74.20	74.44	73.51	73.50	0.98
Fat, %	20.48	20.94	22.19	21.98	1.85

[1] All row values without superscript are not significantly different ($P<0.05$).

Summary

Full-fat Span RS was examined as a protein and energy source in rations of SCWL laying pullets during a laying period of 336 days. The results indicated that:

1. Level of mortality was not significantly affected by the addition of RS to the rations.
2. Incidence of "fatty liver syndrome" increased slightly with increase in the level of RS in the ration.
3. The inclusion in the ration of 0, 5, 10 or 15% Span RS did not significantly affect egg production, although a slight decrease was noted with increased levels of RS in the ration.
4. Egg quality, feed conversion and body weights of birds were not affected by the inclusion of RS in the rations at levels as high as 15%.
5. The size and composition of the livers and hearts were not affected by dietary treatments. The relative weights of the thyroids increased progressively as the level of RS in the ration increased.

GENERAL DISCUSSION

Feeding trials with chicks indicated that the use of raw RS in chick rations resulted in lower weight gain, decreased feed efficiency and consistently enlarged thyroid glands as compared to use of a control ration containing SBM. When the RS was autoclaved, rate of growth and feed efficiency of chicks were improved and relative thyroid weight was decreased in comparison to chicks fed raw RS.

The lower relative thyroid weight obtained with chicks fed rations containing autoclaved RS and the complete absence of myrosinase activity in autoclaved RS tend to suggest that autoclaving may have improved the nutritive value of RS, at least in part, by reducing the goitrogenicity of RS. The importance of goitrogenicity of RS in influencing its nutritive value is further suggested by the results obtained when the use of Span and Bronowski RS was compared (Span RS contained about five times as much glucosinolates as Bronowski RS and so was apparently more goitrogenic). When raw seed was used, the ration containing Bronowski seed gave superior performance to the one containing Span seed. When both varieties were autoclaved (and presumably the goitrogenicity reduced), performance of chicks fed rations containing either 20% Span or Bronowski RS were similar. Thus other characteristics of Bronowski RS which were different from those of Span RS were probably not as important as the factor or factors which were affected by autoclaving. Improvement in the feeding value of RS due to autoclaving has previously been reported (Gray *et al*., 1958).

The feeding value of rations containing autoclaved RS was improved by supplementation with methionine and arginine; though the increase in rate of growth was not significant in all trials, it occurred consistently. The improvement may have been due to increased nutrient utilization or improved amino acid balance. The response to methionine supplementation is perhaps not surprising since the methionine content of all rations was below the requirement level (NAS - NRC, 1971). Moreover, the availability of methionine in RSM may be less than in SBM (Oh et al., 1972). The stimulation of growth of chicks caused by supplementing ration containing RS with arginine has been observed elsewhere (Leslie, 1973).

The apparent lack of response to the addition of lysine (Trial 3) is at variance with the results of Klain et al. (1956) and March and Biely (1971) who reported that RSM rations for chicks were improved by lysine supplementation. Klain et al. (1956) observed improvement from lysine supplementation only when a high level (22 to 43%) of RSM was included in a 24% protein ration and not when the ration contained only 11 to 15.5% RSM. March and Biely (1971) noted the beneficial effect of lysine supplementation with a low protein ration (15 to 16%) with RSM contributing 4% protein to the ration. Moreover, destruction of lysine by heat-induced reactions in the meal during commercial processing have been demonstrated (Gray et al., 1957; Clandinin and Tajcnar, 1961). The data in Table 7 show lysine to be slightly higher in RS obtained after autoclaving than in RSM obtained by commercial processing.

Although differences in weight gains between chicks fed the control ration and those fed the rations containing autoclaved RS were not always significant, weight gains of the control groups were consistently higher than those fed autoclaved RS rations without methionine and arginine supplementation. Results from Trials 7 and 8 tend to suggest that the slight superiority of the control group could be attributed to the higher retention of energy on this ration. The M.E. of the control rations was significantly higher than that of the rations containing autoclaved RS although protein retention and utilization were similar for both rations. This suggests that with higher M.E. on the control ration and with approximately the same feed consumption, more utilizable calories were available to chicks fed the control ration than to chicks fed rations containing autoclaved RS. Consequently, more calories were retained in the carcasses of the control chicks resulting in fatter carcasses and heavier weights.

The lower M.E. observed with rations containing unextracted RS might be attributed, in large part, to lower fat utilization by chicks fed these rations as compared to that by chicks fed the control ration, a fact demonstrated by results of Trial 8. Substitution of RSM and RSO for 20% unextracted RS gave weight gains and energy utilization comparable to those on the control ration. This suggests that the lower metabolizable energy of the ration containing unextracted rapeseed may have been caused by a physical barrier to fat utilization in RS as compared to fat utilization when an equivalent amount of free RSO was included in the ration. Similar results with soybeans were reported by Renner and Hill (1960); and Carew and Nesheim (1961) who observed that the absorbability of soybean oil was lower from ground soybeans than when soybean oil as such was fed.

The inclusion of RS, RSM and RSO in the ration of chicks did not cause any appreciable enlargement in the livers and hearts of chicks.

Even where a slight enlargement was observed, it was apparently due to a higher proportion of moisture or protein rather than increased fat deposition in the livers and hearts. These observations are contrary to those made by Abdellatif and Vles (1970b, 1973) with ducklings; and by Beare-Rogers (1970), and Abdellatif and Vles (1970a) with rats.

Some of the difference in effects of RS, RSM and RSO on the livers and hearts of chickens as compared to other monogastric animals may be attributed to species effects; but others may relate to length of treatment. Lall et al. (1972) showed that the myocardial damage caused by dietary RSO in rats and ducklings were not produced in growing male chickens. Results of Abdellatif and Vles (1970a), Beare-Rogers (1970) and Kramer et al. (1973) suggested that peak lipid deposition in the heart and liver of rats occurred 3 to 7 days after rats were fed diets with RSO, but decreased thereafter. It is possible that similar mechanism operates in young chicks.

Some reports have indicated that a high level of erucic acid in RSO is required to cause lipid accumulation in livers and hearts of animals. Abdellatif and Vles (1970c), Vles and Abdellatif (1970), Lall et al. (1972) and Kramer et al. (1973) noted that fat accumulated in livers and hearts of experimental animals when high-erucic acid was used. In the trials reported herein, the erucic acid content of the oil was only 3.1% and was probably not high enough to cause enlargement of, and fat accumulation in, the hearts and livers of chicks.

The failure to note accumulation of fat in the livers and hearts of chicks may also have been related to the level of oil fed.

The highest level of RS (40%) used in the above trials contributed only 16% RSO to the rations. Rocquelin _et_ _al_. (1970) observed that a level of 15% RSO had no adverse effects on the livers and hearts of rats. In contrast, Abdellatif and Vles (1970b) observed that fat accumulation in the livers and hearts of ducklings occurred only when RSO contributed at least 30% of the calories in the ration; while for rats the minimum level was when RSO contributed 20% of the calories (Abdellatif and Vles, 1970a).

The apparent lack of effects of glucosinolates in RS or RSM on the size and composition of livers and hearts may have been related to the relatively low content of this compound. Oliver _et_ _al_. (1971) reported that liver enlargement in rats occurred only when a high-glucosinolate (_Brassica_ _napus_) RSM was included in the ration. Matsumoto _et_ _al_. (1968) observed that even the inclusion of 0.05% pure goitrin in chick starter rations did not appreciably affect the liver weights.

The productive performance of laying hens when RSM was included in the ration at varying levels was generally similar to results reported previously (Clandinin _et_ _al_., 1972). Inclusion of 5 and 7.5% RSM had essentially no effect on egg production but 10% RSM significantly depressed egg production and increased level of mortality. Haugh unit values, specific gravity of eggs, body weight and feed conversion were not adversely affected by the levels of RSM used. The observation that egg weight was not significantly affected by the inclusion of RSM in the ration is in agreement with the results of Clandinin _et_ _al_. (1966a); Cardin _et_ _al_. (1968); Kubota and Morimoto (1969); Clandinin _et_ _al_. (1972) but is contrary to those reported by Sell _et_ _al_. (1968);

Summers et al. (1971).

The effects of RSM on the organs of laying hens observed in these trials were similar to those reported elsewhere. The significant thyroid enlargement as a result of including RSM in rations of laying chickens is consistent with similar observation made by Kubota and Morimoto (1969); Jackson (1970); and Summers et al. (1971) and may be related to the glucosinolate present in RSM. Liver size, dry matter and lipid contents were not significantly affected by dietary treatments, results consistent with those of Jackson (1969, 1970) and Summers et al. (1969). Likewise, liver protein content and the size and composition of the hearts of laying chickens were not affected by the dietary treatments used.

Incidence of fatty liver syndrome tended to increase with increased levels of RSM in the ration but occurrence of "fatty livers" was not confined solely to the RSM rations. Deaths due to "fatty liver syndrome" only reached an appreciable level when the level of RSM in the ration was increased above 5%; but even when 10% RSM was used, the incidence of "fatty liver syndrome" did not reach alarming proportions. Jackson (1969) reported high mortality in Hyline laying birds fed RSM in their ration and attributed the main cause of deaths to liver haemorrhage ("fatty liver syndrome"). Unlike the results of Jackson (1969) with Hyline birds, only a few of the SCWL pullets examinedat the end of the trial showed evidence of liver haemorrhage which had not proved fatal. In view of the failure to observe increased fat deposition in the livers of RSM-fed groups and similar findings by Jackson (1969) and Summers et al. (1969), one is tempted to agree with the contention of Hall (1972) that the term "fatty liver syndrome" is a misnomer, although the lesions observed are those typical of "fatty livers".

Inclusion of a high level of RS (15%) in rations for laying birds resulted in increased mortality and decreased hen-housed production but the adverse effect was less than that obtained by Leslie and Summers (1972). A possible explanation for the differences noted is the fact that they used unprocessed RS while steam-heated RS was used in the trial conducted here. This suggests that it would be desirable to process RS before including it in laying rations. The observation that mortality increased and that "fatty liver syndrome" accounted for some of the mortality when 10 or 15% RS was included in the ration suggests that restrictions should be placed on the level at which RS may be used in laying rations.

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APPENDIX 1

Procedure for analysis of carcass, heart and liver.

Chicks were fasted overnight before being selected either for determination of carcass composition or removal of the liver and heart samples. Carcasses, hearts and livers were stored at -30C until they were analysed.

At the time of analysis, chick carcasses were thawed at room temperature and the digestive system freed of any remaining feed. The carcasses were then freeze-dried to constant weight after opening up the skull, thighs and abdomen and percentage dry matter was calculated. It took approximately 72 hours to attain constant weight.

The dried carcasses were digested with 6N HCl (4 ml per gram of dried carcass weight) in 600 ml beakers for 2 hours on a reflux apparatus (Gold-Fisch) conventionally used for crude fibre determination. For one week old chicks, digestion was completed within 1 hour. Digested carcasses were transferred to 1 or 2 liter volumetric flasks and made up to volume with water.

The amount of fat in the carcass was determined by the A.O.A.C. methods (1965). In the procedure, 20 ml. aliquots of the digests were filtered through Whatman No. 42 filter paper, and the residue washed free of acid with hot distilled water. After air-drying, the residue was extracted with petroleum ether for 12 hours and percentage fat was calculated.

For crude protein analysis, 2 ml aliquots (4 weeks old chicks) or 5 ml aliquots (1 week old chicks) were transferred to 800 ml kjeldahl flasks and crude protein was determined by A.O.A.C. methods (1965). All determinations were done in duplicate.

The percentage of fat and protein in the hearts and livers were determinedby the same procedures as were used for carcass analysis. The digested samples were diluted to either 250 or 500 ml and 50 ml samples were used for fat determination and 20 ml samples (heart) or 10 ml samples (liver) were used for the determination of protein.

APPENDIX II

Procedure for the assay of myrosinase activity in rapeseed.

Rapeseed was ground to a fine consistency and the ground sample extracted with petroleum ether to produce a meal.

Acetate buffer (100 ml), pH 6.0, was added to 1 gram seed meal samples and the mixture shaken at room temperature for 1 hour. The mixture was then filtered through a Whatman No. 42 filter paper and 2 ml of the filtrate was diluted with deionised water to 100 ml in a volumetric flask.

Sinigrin (allyl glucosinolate) solution was prepared by dissolving 0.005 gram sinigrin in 100 ml of deionised water in a volumetric flask.

To 100 ml of the diluted acetate buffer extract of the seed meal samples was added 20 ml of sinigrin solution. The absorbance of this mixture was then read immediately at 228 mu using a Beckman DB-G spectrophotometer (in order to obtain zero-time absorbance). The absorbance of the mixture was also read after leaving the sinigrin and extract in contact for 6 hours. The decrease in absorbance of the mixture of sinigrin and extract at 228 mu after 6 hours was used as a measure of the myrosinase activity.

Appendix III

Analyses of variance - Source, degrees of freedom (df) and Mean Squares - Chick Trials 1 to 4.

Source*	df	Mean Squares				df	Mean Squares		df	Mean Squares			
		wt gain g	Feed conversion g feed/g gain	wt gain g	Feed conversion g feed/g gain		Thyroid wt mg/100g body wt			wt gain g	Feed conversion g feed/g gain	wt gain g	Feed conversion g feed/g gain
		Trial 1		Trial 2			Trial 1	Trial 2		Trial 3		Trial 4	
T	7	29559	0.005	67957	0.007	7	28.8	15.2	11	11067	0.004	65237	0.021
R/T	8	13455	0.003	3926	0.006	8	12.6	10.1	12	3399	0.002	2518	0.004
C/RT	304	5053		3021		16	7.7	6.8	456	2298		3027	

Source	df	Mean Squares									
		Thyroid wt mg/100g body wt		Organ weights (g/100g body wt) - Trial 4					Carcass - Trial 4		
				Spleen	Testes	Pancreas	Heart	Liver	Dry matter %	Fat %	Protein %
		Trial 3	Trial 4								
T	11	8.8	28.8	0.001	3E-5	0.002	0.01	0.85	5.5	47.8	31.9
R/T	12	4.6	6.4	0.001	3E-5	0.002	0.003	0.08	1.8	15.1	13.8
C/RT	24	5.9	6.6	0.001	2E-5	0.002	0.003	0.15	1.3	9.6	9.3

* T = treatment; R = replicate; C = chick.

Appendix IV

Analyses of variance - Source, degrees of freedom (df) and Mean Squares - Chick Trials 5 and 6.

		Mean Squares			Mean Squares		
Source*	df	Wt gain g	Feed conversion g feed / g gain	df	Thyroid wt mg/100g body wt	Liver wt g/100g	Heart wt body wt
Trial 5							
T	6	69858.0	0.24 E-01	6	27.1	8.3	0.47 E-02
R/T	7	466.8	0.24 E-02	7	7.2	8.2	0.62 E-02
C/RT	266	2738.2		14	7.4	8.2	0.30 E-02
Trial 6							
T	8	25352.0	0.16 E-01	8	26.4	0.46	0.69 E-02
R/T	9	2741.1	0.77 E-02	9	5.2	0.12	0.18 E-02
C/RT	342	1858.5		18	7.2	0.25	0.24 E-02

		Mean Squares								
		CARCASS			HEART			LIVER		
Source	df	Dry matter %	Fat %	Protein %	Dry matter %	Fat %	Protein %	Dry matter %	Fat %	Protein %
Trial 5										
T	6	3.3	39.0	43.2	6.4	29.4	68.7	1.0	2.9	20.2
R/T	7	1.1	5.9	2.6	9.8	16.0	12.2	0.74	0.52	15.4
C/RT	14	1.1	6.4	7.3	4.7	9.7	11.5	1.2	0.47	7.2
Trial 6										
T	8	10.8	39.1	76.7	3.4	29.4	9.1	1.30	2.3	1.9
R/T	9	2.6	7.0	21.2	0.53	4.0	4.0	0.62	1.2	2.5
C/RT	18	1.2	0.50	0.22	0.54	1.7	0.30	1.7	0.55	0.12

*T = treatment; R = replicate; C = chick.

Appendix V

Analyses of variance - Source, degrees of freedom (df) and Mean Squares - Chick Trial 7.

		Mean Squares			Mean Squares			Carcass		
Source*	df	wt gain g	Feed conversion g feed / g gain	df	Thyroid wt mg/100g body wt	Liver wt g/100g body wt	Heart wt	Dry matter %	Fat %	Protein %
T	14	26597.0	0.55E-01	14	47.4	0.16	0.11E-01	11.7	150.7	70.9
R/T	45	1124.1	0.23E-02	45	4.7	0.07	0.17E-01	2.3	7.8	11.8
S	1	0.345E06		1	90.3	0.12	0.69E-01	9.4	305.7	62.9
ST	14	1909.6		14	6.4	0.049	0.36E-02	2.3	6.3	5.2
SR/T	45	1358.9		45	5.0	0.046	0.37E-02	0.98	5.8	4.4
C/SRT	480	1512.2		120	6.0	0.029	0.27E-02			

		Mean Squares											
		Carcass Nutrient Retention				Nutrient Utilization		Heart			Liver		
Source*	df	Dry Matter g	Fat g	Protein g	Energy Kcal	Protein %	Energy %	Dry matter %	Fat %	Protein %	Dry matter %	Fat %	Protein %
T	14	1478.2	966.5	142.0	0.58006E07	19.5	95.4	4.7	30.4	17.4	2.2	20.0	8.3
R/T	45	85.7	35.9	18.9	0.16629E06	3.4	2.9	6.4	12.6	10.1	3.9	8.5	10.8
S	1	5504.7	28.3	2950.1				0.18E-02	902.2	623.4	13.6	13.9	6.6
ST	14	111.6	37.9	17.1				3.2	24.6	22.6	0.59	2.6	9.4
SR/T	45	66.0	33.7	16.6				3.6	15.3	9.1	1.3	6.4	4.0

T = treatment; R = replicate; S = sex; C = chick

Appendix VI

Analyses of variance - Source, degrees of freedom (df) and Mean Squares - Chick Trial 8.

		Mean Squares								
					Retention					
Source*	df	Wt. gain g	Feed conversion g feed / g gain	Caloric Intake Kcal/bird	Dry matter %	Protein %	Fat %	Energy %	M.E.	M.E.$_N$
F	3	0.10377E06	22.8	0.28873E08	32.4	7.1	242.6	36.4	0.62E-01	0.59E-01
P	1	0.27563E07	924.5	0.37528E08	249.2	161.1	192.1	157.0	0.41	0.57
FP	3	673.3	3.1	0.49478E07	3.1	1.9	25.2	2.5	0.17E-01	0.17E-01
R/FP	24	680.9	1.8	0.88547E06	1.7	3.4	0.91	2.4	0.38E-02	0.34E-02
S	1	21271.0								
SF	3	2394.1								
SP	1	27621.0								
SFP	3	2494.0								
SR/FP	24	1338.5								
C/SRTP	256	2434.0								

* F = feed; P = protein; R = replicate; S = sex

Appendix VII

Analyses of variance - Source, degrees of freedom (df) and Mean Squares - Laying chicken Trials 2 and 3.

Source*	df	Mortality %	"fatty liver" %	HHP %	HDP %	Haugh units	Specific gravity	Egg Weight g	Feed Conversion kg feed/doz eggs	Body wt (initial)	Body wt (final)
Trial 2											
T	3	23.9	131.4	29.2	16.3	0.84	0.13E-05	0.095	0.69E-02	0.23E-03	0.23E-02
R/T	4	21.1	40.4	3.7	1.2	0.67	0.50E-06	0.23	0.10E-02	0.42E-03	0.15E-02
Trial 3											
T	3	24.2	77.1	26.0	8.0	0.91	0.15E-05	0.029	0.90E-02	0.38E-03	0.15E-02
R/T	4	42.6	6.3	13.8	2.6	0.53	0.13E-06	0.032	0.17E-02	0.46E-03	0.24E-02

		Relative organ weights			Absolute weights		Liver			Heart		
Source*	df	Thyroid mg/100g body wt	Liver g/100g body wt	Heart	Liver g	Heart g	Dry matter %	Fat %	Protein %	Dry matter %	Fat %	Protein %
Trial 2												
T	3	2916.7	0.054	0.21E-02	9.5	0.66	1.0	9.6	1.2	0.075	1.7	0.28
RT	4	84.5	0.54	0.75E-02	36.6	0.43	6.3	11.2	13.6	0.14	4.2	5.3
C/RT	88	142.1	0.26	0.29E-02								
Trial 3												
T	3	6321.9	0.73E-02	0.48E-02	1.9	0.082	1.4	13.7	10.4	0.47	1.3	0.46
R/T	4	103.1	0.33	0.36E-02	14.6	0.19	4.0	78.9	35.8	0.42	6.8	1.9
C/RT	88	186.8	0.35	0.18E-02								

* T= treatment; R = replicate; C = chicken